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OF THE

NATIONAL BUREAU OF STANDARDS

Annual Report for:

INSTITUTE FOR BASIC STANDARDS

INSTITUTE FOR MATERIALS RESEARCH

INSTITUTE FOR APPLIED TECHNOLOGY

UNITED STATES DEPARTMENT OF COMMERCE
Alexander B. Trowbridge, *Secretary*
John F. Kincaid, *Assistant Secretary for Science and Technology*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

1967
Technical Highlights
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INTRODUCTION

MOVE TO GAITHERSBURG SITE

Most of the Washington, D.C., staff of the National Bureau of Standards completed their move to new facilities in Gaithersburg, Maryland. This new laboratory complex, the culmination of more than a decade of planning, constructing, and transporting, provides NBS staff the opportunity to meet the challenge of the Nation's modern burgeoning industry and science.

The ultra-modern installation contains many new tools as well as an environment vastly improved over the old one. Several of the major new tools such as the linear electron accelerator and a million-pound deadweight testing machine are in use, and a major nuclear reactor is due for operation during the coming year. Both the special and general purpose laboratories incorporate modern equipment and are designed to permit staff flexibility in meeting the national demands for new and improved calibration services, standard reference materials, measurement standards, measurement methodology, evaluated data on the properties of materials, systems studies and advisory and consulting services to the other governmental agencies, industry, commerce and education, particularly in science and engineering. The move into the new laboratories was commemorated with a dedication of international scope.

DEDICATION OF NEW FACILITIES

Secretary of Commerce John T. Connor presided at the formal dedication of the new NBS facilities on November 15, 1966. In an address to about 3,000 distinguished guests from science, industry and Government from this country and abroad, Secretary Connor referred to the new facilities as ". . . a blue chip investment—a national investment in progress, an investment made by all the people (which) will pay untold dividends to American science, industry, and commerce . . .". A highlight of the dedication was a message from the President of the United States in which Mr. Johnson observed that, "This eminent institution now has the resources for even greater service to America and the world. Throughout its 65 years, the National Bureau of Standards has advanced the frontiers of measurement in pace with the increasing demands of science and industry."

Dr. A. V. Astin, Director of the National Bureau of Standards, speaks at the dedication of the Bureau's new laboratory complex at Gaithersburg, Md., on Tuesday, November 15, 1966. Left to right: Lewis L. Strauss, former Secretary of Commerce; Rev. Edward G. Latch, Chaplain of the House of Representatives; Dr. Donald F. Hornig, Director of the Office of Science and Technology; Secretary of Commerce John T. Connor; Dr. Astin; Congressman B. B. Conable, Jr., of New York; Associate NBS Director Robert S. Walleigh; Dr. Edward U. Condon (partially hidden), former Director of NBS; and Dr. J. Herbert Hollomon, Assistant Secretary of Commerce for Science and Technology.

Symposium on Technology and World Trade

Immediately following, and in a real sense as part of the dedication ceremonies, NBS was host to a Department of Commerce sponsored symposium where over 500 internationally known dignitaries, leaders in the fields of industry, education, and commerce discussed technology and world trade. The purposes were:

- To examine and forecast the impact of technology upon the patterns and conduct of international trade and investment,
- To consider the international environment needed for the wider generation and utilization of technology,
- To explore prospects for evolving policies and institutions that promote economic development through technology and trade.

This week of dedication was climaxed with an open house in which approximately 20,000 guests toured the facilities and visited the laboratories in a day-long event.

NBS Publishes History

In keeping with the spirit of the Dedication, NBS released *Measures for Progress*, a history of the first 50 years of NBS. The book recounts and documents the critical role played by the Bureau and in particular the major contributions of individual scientists of the staff in the explosive growth of America's science and industry over the first half of the twentieth century.

LEGISLATION AFFECTING NBS

Fair Packaging and Labeling Act of 1966

NBS has been assigned important responsibility in the Department of Commerce's activities under the Fair Packaging and Labeling Act passed by the Congress in 1966. NBS is responsible for identifying undue proliferation in the weights, measures, or quantities in which any consumer commodity is being distributed for retail sale. The Bureau must also determine whether this proliferation impairs the consumers' ability to make value comparisons.

When NBS determines that proliferation does exist, it will invite the manufacturers, packagers, and distributors of the commodity to participate in the development of a voluntary industry packaging standard.

If, one year after this request is made, it becomes apparent that no standard is going to be published, or if a published standard is not being observed, the Secretary of Commerce must report the situation to the Congress. He must state what efforts have been made to arrive at a voluntary standard and then recommend whether the Congress should enact legislation providing regulatory authority to deal with the situation.

Pending Legislation

At the end of the fiscal year, there were five bills under consideration by the Congress which, if passed, would affect the National Bureau of Standards:

- The Fire Research and Safety Act of 1967
- Amendments to the Flammable Fabrics Act
- Standard Reference Data
- International Standards
- Metric System Study

The proposed Fire Research and Safety Act of 1967 would amend the Organic Act of the National Bureau of Standards to authorize a comprehensive fire research and safety program. In the program, NBS would gather comprehensive fire data, conduct intensive laboratory and field research on the nature of fire, educate and train fire pro-

tection and firefighting personnel, and support demonstrations of improved and experimental fire protection and safety techniques.

The proposed amendments to the existing Flammable Fabrics Act would provide a mechanism for continued evaluation and revision, when necessary, of the flammability requirements under the Act. Revision would keep the requirements up-to-date and give to the consumer the most effective protection against clothing fires that the state of technology in any time period could offer. The amendments would also provide for extension of the Act to cover flammable interior furnishings, and authorize investigation and research to extend knowledge and strengthen ability to combat flammable fabrics problems.

The Standard Reference Data legislation would give to the Secretary of Commerce (and thence to NBS) the responsibility of extracting from the scientific literature important data on the properties of materials, important physical constants, and so forth. The Act would provide for critical evaluation of the data, to identify the "best values." Such evaluation would compress the amount of material a researcher has to wade through, saving American science and industry much time and money, and also give the researcher more confidence in the numbers he uses.

The proposed International Standards Act is designed to promote and support U.S. participation in international standards development. If it is passed, the Department of Commerce, and NBS in particular, would seek to increase the participation of American industry, technical and trade societies, and private standards making bodies in the international standards making procedure. This participation would insure that the U.S. point of view is not overlooked in the writing of international standards, and thus prevent the U.S. from being frozen out of world markets because of restrictive standards.

The Metric System legislation would authorize a study of the effect upon the U.S. of increased use of the Metric System throughout the world and development of recommendations for an action program to deal with the problem.

EXPANSION OF THE RESEARCH ASSOCIATE PROGRAM

The NBS Research Associate Program is an important vehicle for cooperation with industry. Under this program, a company can send one or more of its scientists to NBS to work with Bureau people on problems of mutual interest. The problems must be non-proprietary in nature, and broad enough to be of interest to a broad segment of American industry. Both the Bureau and the sponsoring company benefit from this cooperation. Because the company pays the salary of the Associates, the Bureau's resources are multiplied at little cost

to itself. The visiting researchers get the benefit of NBS facilities and expertise in their work, and they return to their companies with broadened background and capability.

Recently NBS has been putting increased emphasis on the Research Associate Program, and industry has been participating enthusiastically. Among the companies sponsoring new Research Associates are AiResearch Manufacturing Company, American Cyanamid Company, Control Data Corporation, Dow Chemical Company, International Business Machines Corporation, Ferro Corporation, The Procter and Gamble Company, and the St. Louis-San Francisco Railway Company.

GENERAL TRENDS

Future requirements of American industry, commerce and science dictate the future of NBS. These requirements, and means of monitoring and evaluating them, have received particular attention during the past year. Ability to fulfill the traditional NBS role of leadership in developing the measurement methods and standards needed for industry, commerce, and science is being severely challenged by the rapid advances and wide application of science and technology.

As industry and society are becoming more complex and technically oriented, NBS programs are also changing. Even in specifically technical areas such as glass, paper, ceramics, metallurgy and corrosion, NBS programs have changed in the last few years from a craft orientation to a science-based orientation. As a result, the output of data, standards and methodology have much greater precision, meaning and usefulness. The trend is for NBS to become increasingly concerned with broader social, economic, and political problems and programs of the Nation. Solutions of many of these problems—in areas such as transportation, pollution, resource development, education, power development, and health—depend on technology, and in particular the ability to measure, control, produce, or evaluate meaningful parameters in order to diagnose, treat, engineer and evaluate safe, reliable, useful products. NBS now assumes responsibility for developing data for decision making on such questions as what transportation system is best suited for the northeast corridor of the United States, what are the performance requirements for low cost housing, and other systems problems involving a combination of technology, economics, logistics, and sociology. In support of these new activities, NBS has taken advantage of the rapid advance in management tools and procedures and has developed a technical analysis program which provides service not only for NBS operations and programs but also for other Government agencies to aid in their decisions, efficiency and effectiveness.

To some, these newer system responsibilities may seem removed from historical Bureau interest in measurement. In fact, these new

responsibilities are simply an extension of the measurement concepts and disciplines into new areas needing evaluation and quantification. Research on the safety performance of vehicles is concerned with evaluating in a scientific manner the performance of the parts, subsystems and systems of an automobile or other vehicle—as well as the people involved. In most cases methodology used in measuring the important phenomena may be identical to that used in the more traditional work of NBS. Standards, measurement methods, and procedures are now being developed for the computer industry, transportation networks, and industrial operations in much the same manner that the electrical and mechanical or ceramic industries were assisted in the past. In all cases, the end product is a number or set of numbers which defines material, device, or system performance. These numbers are the basis for informed decision and action.

THE NATIONAL MEASUREMENT SYSTEM

All of this activity points up the need for looking at the complex measurement process as a system. Measurement is a basic and necessary activity in all aspects of human endeavor, and especially in science and technology. In order to define meaningful goals and insure a smooth-functioning national measurement activity, decisions must be made in light of the systems concept.

Measurement activities are rapidly changing and increasing in complexity, so much so that it would be useful to take a fresh look at our national measurement system as a whole and up-date our understanding of how its components interact. The following section describes the Bureau's current concepts of the national measurement system.

THE NATIONAL MEASUREMENT SYSTEM

The rapid advancement of technology in the twentieth century has been responsible for the development of a wide variety of complex systems, ranging from those of hardware—such as automobiles, aircraft, missiles, and computers—to social systems involving both hardware and people in various combinations of networks. Examples of these social systems include the Nation's communication, transportation, defense, education, medical, and legal systems.

A SYSTEMS APPROACH TO MEASUREMENT

The national measurement system is still another social system which has grown up in the United States, albeit with little formal recognition. Recently, there has been increased awareness and understanding of the all-pervasive nature of the Nation's measurement activities and of their economic importance.

In their totality these social systems—the transportation system, the legal system, and so on—form the environment in which the individual must live and function. Diverse as they are, these systems have important features in common. Each has multiple interfaces with the others and with their counterparts in other nations, and each consists of two fundamentally different sub-systems closely interacting to form the total system.

The two interlocking sub-systems are the "intellectual system" and the "operational system." The intellectual, or conceptual, system consists of a body of rules, laws, conventions, procedures, or definitions ordered into a unified rational structure. This type of system is universally applicable, much like the laws of physics and chemistry. It forms the basis for the construction and functioning of the operational system.

The operational system consists of a set of functional elements each having certain inputs and outputs. These elements interact with each other under the guidance of some central control to accomplish a particular function or mission. In any social system, the functional elements and subsystems are organizations of people. Each such organization performs an appropriate function, in accordance with the corresponding intellectual system, to accomplish the overall mission.

Our national measurement system is part of an international system used by all leading nations of the world, and is the result of a worldwide progression toward increasing sophistication of measurement, both in concepts and in operation.

The National Bureau of Standards is a vital element in the measurement system. NBS serves as a focal point for many of the Nation's measurement activities.

BASIC SOCIAL NEEDS

Three general, ever present needs of our society have brought the national measurement system into being. In meeting these needs, the measurement system, working together with other social systems, enables society to accomplish national objectives such as space exploration, quality education, adequate defense, an improved standard of living, consumer welfare. The three needs are:

(1) *Basic measurements and standards.*—The nationwide need for a complete and consistent system of physical measurement, properly coordinated with those of other nations, requires the ability to make accurate, reliable, precise, and compatible measurements in terms of a common language of units and methodology.

(2) *Matter-materials data and standards.*—There is continuing need for a systematic and readily accessible body of accurate, reliable, precise, and consistent data on the properties of materials in different environments, and for information, reference materials, and conceptual knowledge that will make possible the effective use of such data.

(3) *Technological measurements and standards.*—To an increasing extent, the economy has come to depend on exchange in the marketplace of products and services having a high technological content. This creates a need both for uniformity of product characteristics and for a language for stating user requirements in terms of the performance capabilities of products and standards.

IMPORTANCE OF THE SYSTEM

Estimates of activity within the U.S. measurement system include the measurements made every day by each person—ranging from the relatively crude ones of checking the time or temperature, reading the speedometer, or buying steak by the pound, to the highly sophisticated and often exquisitely complex measurements made in the laboratories of science and industry. Rough estimates indicate some 20 billion measurements are being made every day in this country.

Industries that account for two-thirds of the gross national product invest about $14 billion a year in measurement and expend about 1.3 million man-years in the process. Some $25 billion is invested in measuring instruments and this investment is being increased by some $4½ billion each year. In addition, some $20 billion is invested in research to provide measurement data and about $3 billion a year is being added to this amount. Altogether the annual U.S. investment in measurement is about $50 billion. Operation of the system is more than 90 percent self-financed through its own internal system of charges, fees, and so on. The remainder is contributed by the Federal, state, and local governments.

Studies have been made of the growth pattern of manufacturing industries in relation to the amount they invest in measurement. It is

strikingly evident that the industries growing most rapidly are those that invest, in proportion to output, the most in measurement.

FUNCTION OF THE NATIONAL MEASUREMENT SYSTEM

The essential function of the national measurement system is to provide a quantitative basis in measurement for (1) interchangeability and (2) decisions for action in all aspects of daily life—public affairs, commerce, industry, science, and engineering.

Interchangeability is of fundamental importance in modern society. Once a measurement system with a set of agreed-upon units and standards has been established, it will serve as a firm basis for the interchange of goods and services in the mass markets of modern commerce, of machine parts and devices in industry, and of scientific and technical information. Such a system makes it possible for any plant to mass-produce materials, parts, and systems that are interchangeable with those made in plants in other parts of the country. Without this basis for interchangeability, the industrial economy we know today could not exist. Likewise, if results obtained in one laboratory are to be useful in another, they must be expressed in a measurement system common to both laboratories; otherwise, confusion would result when two laboratories attempted to exchange information.

Twentieth-century man must make numerous decisions throughout the day, and many of these decisions are based on measurement. For example, an aircraft pilot must read a number of measurement output dials in order to make vital decisions during a flight. In previous times, with fewer planes traveling at slower speeds, less information was needed. But today, with commercial and private aircraft clogging major airports and new designs which permit air travel at supersonic speeds, an entire new range of highly accurate information must be immediately available to aid pilots in making split second decisions.

Similiar needs exist in many areas of daily activity and especially in science and technology. Bureau scientists can measure time accurate to a few parts in 10^{12}—many orders of magnitude greater than needed by the man on the street—but one hundred times *less* than the accuracy being sought by technicians involved in the space program.

The needs of defense programs, high speed transportation systems, complex computer operations, and may more scientifically oriented activities made possible by the rapidly expanding technology demand readily available, highly accurate measurement. To the extent that the needed measurement and associated techniques are not available, technological advancement will be correspondingly hampered.

To provide a basis for both interchangeability and decision-making throughout the Nation, all measurement must be compatible with each other. The airplane pilot's decisions based on measurement must be compatible with the measurement of others if he is to stay on course,

avoid collisions, and arrive on time. Thus the system operates to provide "constrained freedom." That is, each manufacturer or businessman within the system has complete freedom to make his own decisions and to develop products as he wishes; but at the same time he is so constrained that his activities will be compatible with his environment and he will thus be able to operate successfully.

THE INTELLECTUAL SYSTEM

The intellectual, or conceptual measurement system, is the logical structure that binds together the measurables of science, industry, and commerce. The chain of logic starts with four independent, arbitrarily defined units for the basic quantities—length, mass, time, and temperature. These units (the meter, kilogram, second, and degree Kelvin) are defined by international agreement in such a way that changing the size of any one of them will have no effect on the size of any of the other three.

From these four "basic units" are derived the units for all other physical quantities—such as power, force, current, or resistance—in accordance with the definitions and equations of physics. The quantity of speed, for example, is obtained as a length divided by an interval of time. Once the units of length and time have been defined, a unit of speed can also be defined. The unit of speed is then a derived unit, dependent in size on the size of the units of length and time. In the same manner, the unit of acceleration is derived from the units of speed and time. Continuing in this way, one eventually arrives at a consistent system of units; that is, a system consistent with the equations of physics.

This type of system has the important advantages of coherence and simplicity of computation. Using a consistent system of units, one can proceed by means of definitions and measurement rules to establish another category of measurables: the intrinsic properties of substances, such as density. This category includes a set of quantities very similar to the basic and derived physical quantities to which they are related by their definitions.

Similarly, by means of definitions, relationships, and test schemes, one can go from the properties of substances to the performance characteristics of simple devices—for example the amplification factor of a vacuum tube or the sharpness of a razor blade. Then, proceeding in the same direction one can go to the performance criteria of systems—like the reliability of a computer—feeding in test schemes and formulations to form a progressive, coherent set of measurable quantities.

In 1960 the International Conference on Weights and Measures adopted an International System of Units (abbreviated SI for Sys-

teme International). The SI is a consistent metric system of units based on six fundamental physical quantities in terms of which all others are to be defined so as to be consistent with the generally accepted equations of physics. These quantities and their units are mass (Kilogram), length (meter), time (second), temperature (degree Kelvin), current (ampere), and luminous intensity (candela).

THE OPERATIONAL SYSTEM

The operational system consists of people and organizations which insure proper linkage of the U.S. system to the international measurement system, analyse and work on the pool of unmet needs, and maintain and disseminate information on the reservoir of capability that users may draw upon. There are three major networks which comprise the operational aspects of the measurement system.

First there is the *instrument network* which provides calibrated traceable instrumentation, consistent and compatible with the national standards, for making measurements. This network is tied to the intellectual system through the national standards of physical measurement.

Then there is the *data network* which provides the user of the system with critically evaluated data on the intrinsic properties of materials—data that investigators have obtained in measurements based on the national standards. This network thus gives the user in many cases a "ready-made answer" to his measurement problem so that he does not need to make the measurement himself. The data network is related to the intellectual system through the national standards and the definitions of the properties of substances.

Finally, there is the *techniques network* which tells the user of the system how to make meaningful measurements. This network disseminates knowledge to the user, through publications and other means, so that he will know, first, how to make a given measurement, and second, what it is meaningful for him to measure.

The National Bureau of Standards plays a key role in the operation of each of these networks. The role is one of central Federal leadership, guiding the system as it operates through the voluntary cooperation of American science and industry. Because this leadership must come through general acceptance based on capability, NBS concentrates on generating meaningful outputs—

- developing and maintaining the national standards which serve as the basic core for the three networks
- providing calibration services and standard reference materials for the instrument network
- generating and evaluating data for the data network
- developing methods of meaningful measurement for the techniques network.

The Central Core

The central or basic core of the national meaurement system consists of the four basic standards and some 50 derived standards. The basic four are national standards with coordinating links to international standards. They are developed by starting with a knowledge of materials as a basis for conceiving and defining a unit; then on to a material realization of this unit, and finally to the standard. With the exception of the kilogram, each of the four basic units is now defined in such as way as to be independently reproducible—the meter in terms of the wavelength of the red radiation from krypton-86, the degree Kelvin in terms of the triple point of water, and the second in terms of a transition of the cesium-133 atom.

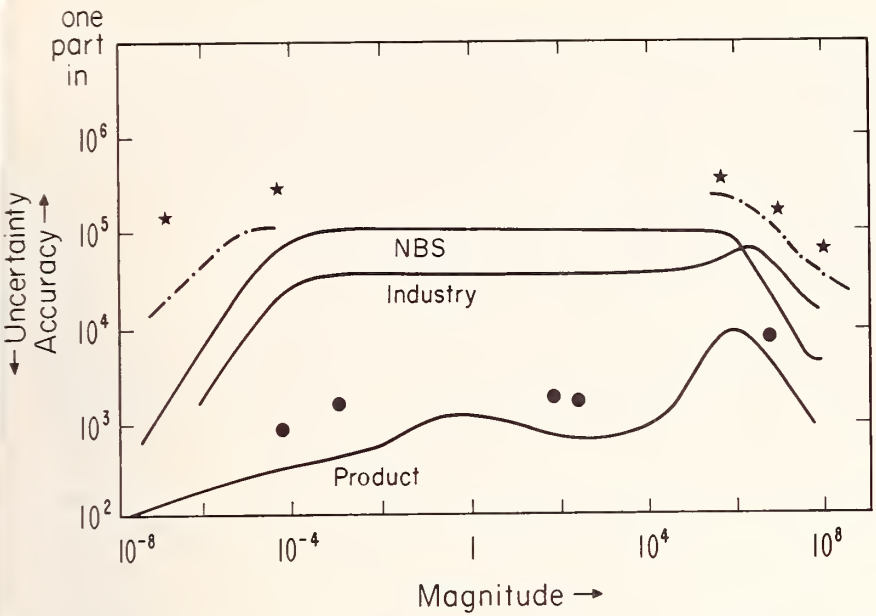
The derived standards are obtained by first defining the appropriate unit in terms of the basic units so that definitions will be consistent with the equations of physics; knowledge of materials can thus be used to realize this unit in as accurate a material form as possible.

Instrumentation Network

Leading outward from the central core of national standards, there is a chain of measurement that provides for measuring all the magnitudes man must deal with. In mass, for example, the range extends from the mass of the earth, or even beyond, down to the mass of the electron, neutron, or sub-particle. This is a vast spectrum of some 50 or 60 orders of magnitude that must be connected through a measurement chain to the defined unit, the kilogram, in order to provide the accuracy required by science and industry at any particular magnitude. Some of these magnitudes can be measured directly by taking multiples or submultiples of the standard, but as measurements are made farther and farther from the central part of the range, it is necessary to use indirect methods, with a corresponding reduction in accuracy.

It is impossible for a single institution such as NBS to make calibrations over the complete range for mass or for any other quantity. The Bureau is thus forced to make basic decisions as to needed range and accuracy. It is Bureau policy to pick calibration points (or in some cases calibration regions) at intervals over the range so that the measurement activities of the country can be coupled to NBS at these points. The Bureau relies on other measurement laboratories in industry and Government to extend calibration to intermediate points between the NBS points, thus covering the range as needed. In this way the national standards in the central core are ultimately disseminated over the entire instrumentation network.

To help in making the basic decisions that are required, NBS is now using accuracy charts to assess its measurement capabilities in various



A generalized accuracy chart of the type used at NBS to make basic decisions regarding priorities within the measurement system.

areas. The figure above is an idealized version of such a chart. The heavy line indicates present NBS capability; the next line down shows what good industrial laboratories can do; the lower line gives accuracies at the ultimate user's level—at the factory bench and in the finished product. The dots indicate the accuracies NBS customers say they need and the dashed lines show where NBS activities now underway are leading. Finally, the stars represent the ultimate needs for capability expressed by important segments of the scientific and industrial community.

NBS staff use this type of chart to show graphically where major efforts are being applied, to indicate goals, to display needs of the national measurement system, and to determine where to concentrate further efforts. The charts aid in resolving such questions as whether it is more important to raise the line representing NBS capability, and thereby bring up the line representing industrial capability, or whether to try to bring the industry line up closer to the NBS line by tightening up the system, perhaps by reducing the number of echelons between the standard and the ultimate user.

Unfortunately, users of the system who send instruments to NBS for calibration are not likely to obtain any knowledge of their own capability to use the instruments to the accuracy with which they have been calibrated, nor can users be certain that accuracy has not been degraded in the shipping process. With this in mind, NBS scientists are now considering ways for tying all laboratories in the country into the measurement system on a self-calibration basis. The aim is to make it

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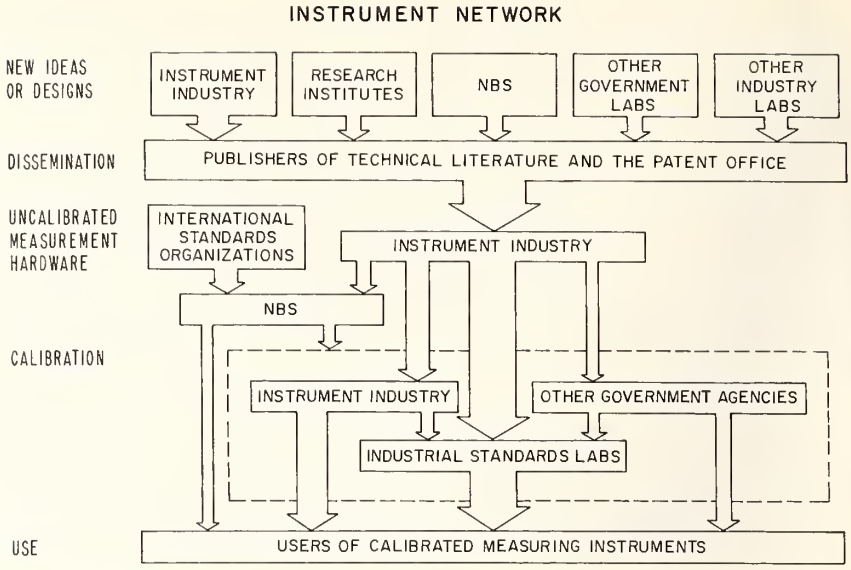


Graphic representation of interactions between various groups in the instrumentation network.

possible for industrial laboratories to do much of the work of calibrating with their own instruments, staffs, and procedures. Having done so, they would then have a measure of their own capabilities and would know how well their instruments could be traced back to the national standards.

Ways in which self-calibration can be carried out include the use of standard reference materials, key data on properties of materials, and circulating standards.

Standard reference materials are highly characterized materials that NBS certifies either for chemical composition, physical state, or with respect to a specific physical or chemical property. The Bureau disseminates materials on request at a fee which covers the cost of preparation and certification. Purchasers use these reference materials to calibrate their measuring process.

A new approach is now being used with great success in the field of mass calibration. The primary aim is to provide techniques for ascertaining that the measurement processes used in different laboratories are compatible. Under this program laboratories do *not* send their mass standards to NBS for calibration; instead they receive two calibrated mass standards from the Bureau and use these weights to calibrate their own sets of weights, and also their measurement procedures. Raw data are transmitted to NBS for statistical analysis by high-speed computers. Thus, emphasis is placed on performance of the measurement process and its ability to produce consistent measurements, rather than on the assignment of values to individual test items.

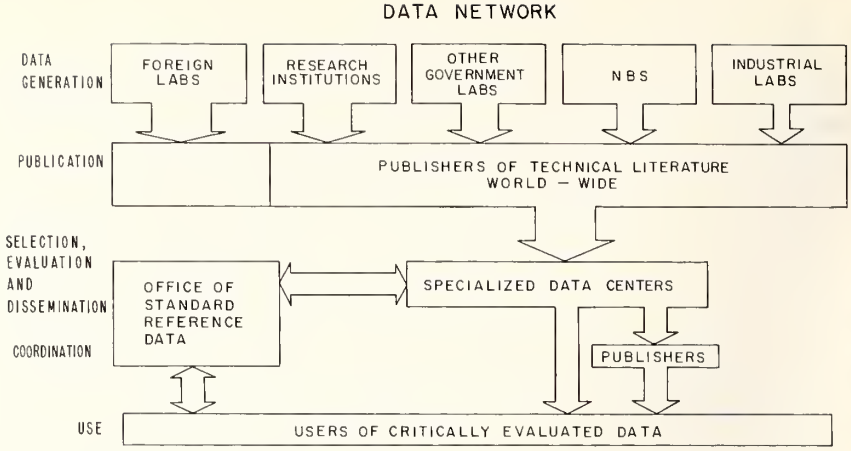
Data Network

The data network offers another important means for enabling the user to perform his own calibrations, for when sufficient data have been obtained to characterize a substance, it then can serve as a reference material for the calibration of instruments that measure the properties of other substances. The use of freezing and boiling points of various substances—the "fixed points" of the temperature scale—to calibrate a thermometer is a good example. Thus, in this network the NBS role is to select certain key materials, to characterize these materials carefully, and to make precise measurements of their properties. In some cases the Bureau makes available not only the data but the materials themselves as standard reference materials. The system can then couple to the properties of these materials and use them as points of reference in building a reservoir of data to meet the remaining needs.

This central function provides a basis for NBS leadership of the system. At the same time it supplies the system with the basic information needed for self-calibration of instruments and measurement procedures, and gives scientists and engineers the data they depend on in designing and building apparatus and equipment. To do the job properly, NBS must obviously have broad competence in materials research and in measurement science.

The corresponding data network for design specifications or performance characteristics of devices and systems is at present quite broad and diffuse. At this stage of the network's development NBS devotes its effort to providing the technical basis for setting meaningful design or performance standards, leaving the actual setting of the standards to the voluntary cooperation of the other elements of the system (except for mandatory standards that NBS is legally required to set).

The data network is of great value in providing a basis for decisions that must rely on measurement. If, for example, an engineer were setting out today to design a new competitive light bulb, there are a great many things he would need to know. Obviously he would need instruments to make direct measurements of the diameter of the bulb, the pitch of the thread, the weight of the materials, the diameter of the wires, and so on. But once he had the capability of making these measurements in production, he would still be a long way from the design of a light bulb. He would need a vast store of such ready reference information as the electrical resistivity and spectral emissivity of tungsten and other competitive materials, the melting point and thermal expansion of glass—in fact, a whole library of data of this kind (which incidentally would also be of value to designers of vacuum tubes and other products). If he has to stop and measure all these properties, he will be investing substantial sums in a research program before he can start his design. On the other hand, if data are already available because someone else has already measured the properties, then he



Graphic representation of interactions between various groups in the data network.

can save this large investment. Once he has found the numbers, he can proceed with the design, provided that he can trust the numbers to be correct.

There is a second important aspect which points up the need for critically evaluated data in the decision process. When an engineer goes to the literature in search of design data, he is likely to get a wide range of value for each property he looks up. If he is designing an industrial process that involves the heat of formation of hydrogen sulfide, for example, he will find in the literature an array of values ranging from 2.0 to 4.9 kilocalories per mole. If he accepts the value "2.0" for the heat of formation of hydrogen sulfide, he might conclude that his planned process will not work and there is no point in going further. On the other hand, if he accepts the value "4.9" he may find that his process will be highly productive and should be pushed. In the absence of critically evaluated data on the heat of formation of hydrogen sulfide, he can do only what is usually done in industry today—seek expert advice if he can find it, make an educated guess, or measure it again himself, adding another value to the list. Unless he is an expert in the measurement of heats of formation, the value he obtains will probably be no better than those already in the literature, and may be much worse.

The solution to this type of problem is to assemble a group of experts who know the field and who can evaluate the various measurements from the literature and obtain a "best value"—the most acceptable and trustworthy value—and can make this value generally available. This is the process of critical data evaluation and compilation. In the data network the primary need is for a core of carefully measured key data that can serve as reference data for the determination of other data throughout the system.

The process of critical evaluation and compilation of data has lagged far behind the generation of data in the literature. As a result, a large backlog of unevaluated data has been built up, and as this backlog continues to grow it has become increasingly difficult for scientists and engineers to find the data they need. Lack of critically evaluated data in conveniently available form has thus become an important and wasteful deficiency of the national measurement system. To remedy this deficiency, the Office of Science and Technology in 1963 established a National Standard Reference Data System and charged NBS with the responsibility for its administration and coordination.

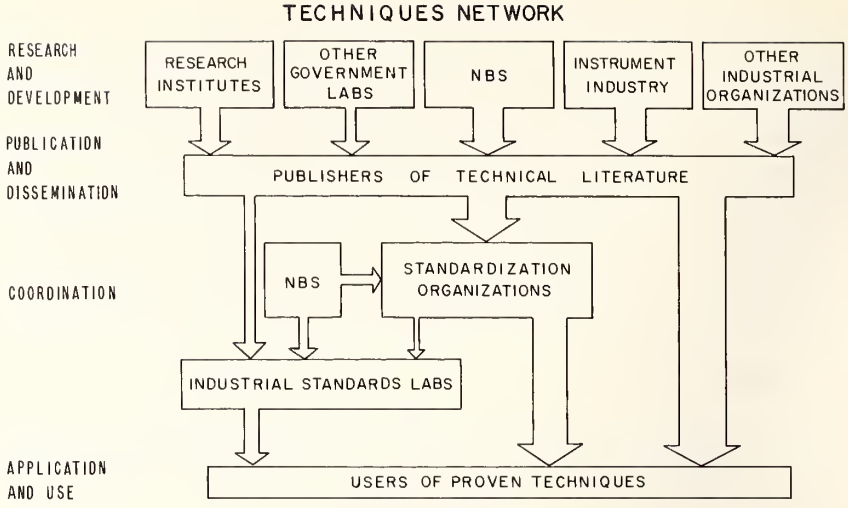
Techniques Network

The techniques network is that part of the national measurement system through which all users of the system can be told how to make optimum use of the measurement capability developed in the instrument network and the data network. Thus the techniques network provides users with the procedures and techniques that make for meaningful measurement.

The term "meaningful measurement" has two distinct aspects. The first is concerned with the ability to measure what one sets out to measure. For example, in attempting to measure the temperature of a particular body at a certain stage of a physical or chemical process, it is sometimes very difficult to be sure that one is in fact measuring the desired temperature, rather than some other temperature within the system. Even though the measurement may be very precise and reproducible, the temperature thus obtained may be quite different from the actual temperature of the body, and thus the measurement can be highly inaccurate.

The other aspect of meaningful measurement is the matter of determining what one should set out to measure in order to accomplish a particular measurement goal. The problem is to find what properties, or combination of properties, or set of physical quantities can be measured, so precise and accurate indications can, by some agreed-upon process, be put together to give a number characteristic of the aspect of the system being measured. It must then also be shown that the chosen procedure does in fact lead to an objective, reproducible measurement.

To make meaningful measurements the materials involved must be characterized in terms of properties that are relevant to the measurement goal being sought and in terms of the environment in which the measurements are to be made. Characterization becomes more difficult and more sophisticated as the interactions of materials multiply and become more intricate, and as the environments become more extreme. Characterizing the bulk properties of a material for various measurement objectives is complex. And obviously the characterization of



Graphic representation of interactions between various groups in the techniques network.

materials in environments of plasma temperatures for example—where even the usual definition of temperature does not apply—is a great deal more difficult than doing so at more mundane temperature ranges.

In this country an extensive network of institutions and organizations has grown up, aimed in one way or another at proper utilization of the national measurement system for the making of meaningful measurements. This techniques network has not yet been as well examined or understood as the instrumentation and data networks. At a minimum, it includes professional journals and other publications; meetings of professional societies; organizations and institutions that provide training in measurement techniques; standardizing bodies such as the USA Standards Institute, the American Society for Testing and Materials, and the International Standards Organization; standards of practice which include agreed-upon procedures for making measurements; and the educational institutions that provide the trained manpower to operate the national measurement system.

As an institution which has developed the capability for leading the national measurement system, NBS has a responsibility for making available the information and know-how it has acquired in developing this capability. To fulfill this responsibility, the Bureau renders consultative and advisory services to standards laboratories, publishes data and information on measurement techniques, sponsors symposia and training courses on measurement topics, and cooperates extensively with standardizing bodies, particularly through participation of Bureau staff members in the committee work of these organizations.

INSTITUTE FOR BASIC STANDARDS

The Institute for Basic Standards (IBS), one of three institutes which comprise the National Bureau of Standards, has as its first responsibility the provision of "the central national basis for a complete, consistent system of physical measurement properly coordinated with those of other nations." As a second responsibility IBS develops and maintains standards for physical quantities and for the measurement of physical properties. In concert with the Bureau's Institute for Materials Research, IBS shares the responsibility for providing physical data on the properties of matter and materials.

Implicit in the assignment of the first responsibility is the recognition that there does exist a national system of measurement and that this system is a centralized one, with a central laboratory which develops and maintains the national standards for physical measurement and provides the starting point for a chain of measurement leading from those standards to the ultimate users of the system. This chain must provide for measurements of all necessary magnitudes, from the properties of atoms to those of the universe.

From the point of view of the ultimate user who faces a measurement problem, such as finding the diameter of a ball bearing or the melting point of a metal, the measurement chain can operate in two different ways: (i) It can provide the user with a proven measurement technique or with a calibrated instrument, traceable back to the national standards, with which he can measure the diameter or the melting temperature. (ii) In the case of the melting temperature or other similar properties, it can provide him with an immediately available answer in the form of critically evaluated data which previous investigators have obtained in measurements based on the national standards.

As the nation's central measurement laboratory, NBS exercises leadership in both these measurement areas. In the Bureau's laboratories the acquisition of standard reference data by precise measurement goes on side by side with research to develop and improve the national standards and associated measurement methods.

PHYSICAL QUANTITIES

The strength and utility of the national measurement system depend fundamentally upon the existence of a complete, consistent system of units and standards around which the system can develop. The In-

ternational System of Units (SI), defined by the 11th and 12th General Conferences on Weights and Measures, is the base for the international system of measurement and for most national systems. Six of these SI units—the kilogram, meter, second, degree Kelvin, ampere, and candela—are the arbitrarily chosen values of six quantities of the physical world—mass, length, time, temperature, electric current, and luminous intensity. Consistent units for other quantities may be derived from these, with appropriate values fixed by the units selected for the basic six. The English system—pound, inch, second, degree Fahrenheit, etc.—and other systems of units are related to the SI units by definite conversion factors.

The research at NBS on physical quantities is concerned with the establishment of these units by international agreement, the realization of the standards which represent them, and the development of a chain of measurement from these standards to the multiples and submultiples needed by our technologically based society. These activities offer an exciting field of technical endeavor which reaches to the frontiers of science and technology. Indeed, the state of sohistication of the U.S. national measurement system is an important gage of the scope and utility of our science and technology. Current work in this area is described below.

INTERNATIONAL BASE UNITS

Length

International Comparison of Laser Wavelengths.—In order to make accurate use of the gas laser in dimensional metrology it is necessary to know the wavelength of the laser light being used. NBS metrologists recently determined the wavelength of the "6328" line of a helium-neon gas laser by direct comparison with the krypton wavelength standard of length. The same laser was then sent to the National Laboratories of Great Britain and the Federal Republic of Germany for similar measurements. None of the results differ from the average of the three—632.991418 nm in vacuum—by more than 3 parts in 10^9. This round-robin helped clarify a mystery that appeared in 1965. At that time each laboratory measured a different laser, with much poorer agreement. It is now clear that lasers, even though of identical manufacture, may have wavelengths differing slightly from one another. Because of this, NBS has established a program that will lead to a calibration service for laser wavelengths.

Time and Frequency

A New Location for WWV.—At 0000 Greenwich Mean Time, December 1, 1966, WWV transmissions were transferred to Fort Collins, Colo. The obsolescent Greenbelt, Md., facility was replaced in its en-

tirety at the Fort Collins site. The new facility located on a site near the present WWVB/WWVL Fort Collins, Colo., not only provides more reliable service throughout the country, but the station is near the NBS Radio Standards Laboratory, which is responsible for its technical and administrative supervision. The transmission building occupies a floor space of 6880 square feet and is located in the side of a hill. It was designed in this manner to prevent deleterious effects to the omnidirectional radiation characteristics of the antennas which are located in an arc of a circle on the ridge of a hill overlooking the building. The half-wave center-fed vertical dipoles are connected to their respective transmitters with rigid coaxial cables and are matched to 50 ohms. An average power of 10 kW is radiated on 5, 10 and 15 MHz, and 2.5 kW is radiated on 2.5, 20 and 25 MHz.

Frequency control equipment consists of three complete and independent frequency generating systems. Each is controlled by a cesium 133 frequency standard that is phase-referenced to the NBS Frequency Standard located at Boulder, Colo. This station maintains a transmitted accuracy exceeding 1 part in 10^{11}.

Frequency-Time Dissemination Research.—Time and frequency have the unique characteristic that enables NBS to distribute them to users by means of standard radio broadcasts. However, the accuracy of the current methods of distributing them has not kept pace with the needs, and therefore, research has been underway on new and improved methods of dissemination. One potential time distribution system being investigated by NBS is the use of satellites. Using the VHF transponder aboard the AFS–1 satellite, an atomic clock at the NASA Mojave site in California was compared to one at NBS, Boulder, Colo., with an indicated precision of about 10 microseconds.

Synchronization of Atomic Clocks.—An important problem in synchronizing widely separated clocks using VLF radio signals is the determination of propagation delays from the transmitter to the receiver. As in electric circuits, the propagation medium at VLF introduces phase and group delays, which need to be known before widely separated clocks may be accurately set to agree with a master clock at the transmitter and therefore with each other. Recent phase velocity measurements have been made with an accuracy of a few parts in 10,000. They were accomplished by using special VLF receivers and an atomic reference standard carried in a mobile laboratory which traversed a path from Boulder, Colo., to Austin, Tex. It was found that the VLF waves travel with a speed of around 99 percent of that of light in a vacuum. Results of these types of measurements are part of a continuing effort at NBS to obtain the basic information needed to

disseminate standard time at VLF using a multiple carrier system devised by NBS several years ago. Such a system, with worldwide coverage, would be invaluable to the nation's space effort by permitting rapid synchronization of the clocks at all the NASA satellite and deep space tracking stations, as well as those of other agencies of the Government, such as the Department of Defense.

Time and Frequency Bulletin Available.—During the past year, at approximately one-month intervals, NBS disseminated to persons requesting it, a Time and Frequency Bulletin giving corrections and announcements for WWV transmissions.

Temperature

Nuclear Resonance Thermometry.—The temperature dependence of the chlorine 35 nuclear quadrupole resonance frequency in potassium chlorate ($KClO_4$) has been measured between 12 °K and 300 °K. It has been shown that it is practical to use this resonance frequency as a thermometer with a precision of one thousandth of a degree in the temperature range 50–300 °K. The sensitivity deteriorates at lower temperatures.

Electric Current

Ampere Determination.—The NBS Pellat-type dynamometer has been modified for use in a new ampere determination. The balance arms were stiffened and a new rotatable coil was wound on a fused silica form. Preliminary results indicate a slightly smaller difference between the NBS and Absolute Ampere than resulted from the 1958 determination. The new determination is, therefore, in somewhat better agreement with the 1958 value published for the NBS Current Balance.

Surveillance of the NBS Ampere.—Continuing measurements of proton precession frequency in the field of a stable solenoid excited by a current defined in terms of the NBS Volt and Ohm, demonstrate that the ratio of these units (as maintained) has not changed by as much as 1 ppm over a six-year interval. In view of other evidence that the NBS Ohm has been stable within considerably closer limits, it may be presumed that the NBS Volt has not changed by as much as 1 ppm. Data now available include the year that has elapsed since the standard cells used to maintain the NBS Volt were moved from Washington to their present location in the Gaithersburg, Md., laboratory.

Absolute Value of g.—An absolute determination has been made of the acceleration due to gravity at NBS Gaithersburg. The work parallels similar research programs in other national laboratories in Europe, Great Britain, Japan, and Australia. It is planned that the values obtained in the different laboratories will be combined to form a new and more accurate basis for geodetic and precise physical measurements throughout the world. The value obtained at the Bureau, 9.801018 m/s^2, after transfer corrections are made, lies close to values already obtained at the International Bureau of Weights and Measures, the National Research Council of Canada, and the National Physical Laboratory near London. All of the results indicate that the old value determined at Potsdam, Germany, around 1905 is about 13 parts in a million too great.

Improved Measurement of Humidity.—NBS has under development a humidity-sensing device particularly well-suited for measurement of rapidly-varying water vapor concentrations in the atmosphere. This new instrument utilizes the effect of ambient humidity on the electrical resistance of a thin film of barium fluoride deposited by vacuum evaporation under carefully controlled conditions. Although the characteristics of the device are still being studied and improved, it has already been put to practical use in a number of important problems and programs requiring measurement of water vapor distribution in the atmosphere. Examples of these applications are: vertical probing of the atmosphere with radiosondes; cloud physics research from fast flying aircraft; micrometeorological studies of atmospheric fluctuations close to the ground; tower investigations of variations in refractive index for radio propagation; studies of the water vapor flux from bodies of water; and measurements of the transpiration of water vapor from crops and forests.

Laminar Flowmeter Performance.—Available data on the performance of laminar flowmeters has been reevaluated and used to derive a meter equation showing their properties as a function of pressure, viscosity, size, gas compressibility, heat transfer, slip flow, and end effects. These meters, which consist of one or more tubes that are long compared to their diameter, are finding increasing application in fluid flow control systems. The new equation has been tested and verified for single channel laminar flowmeters, and has been used to derive a possible treatment of calibration data for multi-channel meters in which the flow is not equal in all channels.

A Model for Hearing.—It is well known that the contours representing equal sensations of loudness for sounds of various frequencies become flatter as the sound pressure level increases. From a study of a model representing the behavior of the ear, it has been proven possible to demonstrate that saturation takes place in that part of the inner ear where partial processing of the sound had already occurred, and where discriminations of intensity and frequency are carried out. The model shows that the flattening of the loudness contours and the limiting of the intensity discrimination that are observed experimentally are related to saturation occurring in the same part of the hearing mechanism.

Improved System for Calibration of Vibration Pickups.—A new system has been developed for the calibration of vibration pickups over the range 10 to 10,000 Hz. Up to now, such calibrations below 2000 Hz have been performed on electrodynamic "shakers" that use a velocity coil as a standard, and those at higher frequencies have been made on piezoelectric shakers. The improved performance of the new system results from the use of a novel moving element of high relative stiffness, combined with the extremely linear motion afforded by making this element part of an air-lubricated bearing. The standard is a piezoelectric accelerometer that is a permanent part of the moving element. Measurements are made using digital circuitry and data reduction on a shared-time computer. Significant improvements in accuracy and speed of calibration have been obtained.

Radiation Induced Acoustic Cavitation.—The negative pressure required to cause cavitation in a liquid can be drastically lowered by irradiation, especially with neutrons. Theory indicates that for sufficiently high neutron energies, the threshold is independent of the energy. However, it was found that for some liquids, including methanol and ethanol, the threshold is still rising with neutron energy at 14 MeV. These results will be studied for applicability to neutron spectroscopy.

Symmetrical Bending of Plates.—Results have been obtained describing the mechanical response of centrally loaded thin circular elastic plates on equally spaced point supports. Equations for design purposes were derived by specializing an existing theory, and the validity of these relations was demonstrated by experiments. Similar studies on thick plates are being undertaken. This information is needed to assure the appropriate use of data on these devices, particularly in capacities greater than 1,000,000 lbf, without significant loss in accuracy. Circular plates serve as structural members in numerous applications which include transferring loads during cali-

brations of elastic force measuring devices, closing the ends of pressure vessels and supporting optical flats during use or measurement.

Nonlinear Constitutive Equations.—New progress has been made in the development of a rheological constitutive equation to describe the mechanical properties of materials which can be classed as elastic fluids (rubber, polymer solutions, etc.) when subjected to large deformations and/or flow velocities. It has proved possible to relate viscosity and normal stress as a function of rate of shear to dynamic viscosity, measured using small sinusoidal deformations as a function of frequency. This formulation predicts that the dynamic viscosity as a function of frequency and the apparent viscosity as a function of rate of shear should coincide over only a limited range, and gives a more complicated relationship between these two functions which holds over a much wider range. It is now clear why previous, empirical attempts to relate these two functions have been successful over only a limited range.

ELECTRICAL QUANTITIES—DC AND LOW FREQUENCY

Thermal Voltage Converters.—A new NBS set of thermal voltage converters, and an emf comparator for evaluating and using them, has greatly simplified high-accuracy a–c voltage measurements and ac–dc difference tests at audio frequencies. The converters consist of two thermoelements (2.5 and 5 mA) and five plug-in resistors, to provide voltage ranges from 1 to 600 V with ac–dc differences less than 10 ppm. With the emf comparator, which has a readout directly in ppm, the differences between adjacent voltage ranges may be intercompared to a few ppm. Six such intercomparisons (less than half those required with the earlier NBS standards) verify the continued stability of the entire set of voltage converters. The set may then be used with the comparator to make ac–dc tests of other transfer standards, and to make voltage measurements by reference to suitable d–c standards.

Capacitance Standards.—The bank of 10-pF fused silica capacitors, constructed in 1964, has now been under observation for more than two years. Most of them appear to be stable to better than a part in 10^7 over this time interval. Units from the group are being circulated to other national laboratories for international comparisons, and a special bridge was constructed for the International Bureau of Weights and Measures (BIPM) so that they might also compare low-value standards. This bridge has been checked out and installed at BIPM by a member of the NBS staff.

Voltage-Ratio Measurements.—A "boot-strapping" technique was developed to evaluate inductive voltage dividers at 10 kHz with an

accuracy estimated to be 1 part in 10^6. This represents an improvement in accuracy at this frequency by a factor of about 3 and has the additional advantage of being an "absolute" method in that it does not rely on the calibration of any other ratio devices. It is expected that further refinements will soon yield an accuracy approaching 1 in 10^7.

ELECTRICAL QUANTITIES—RADIO

Radio standards—from 30 kHz up to and including microwave, millimeter wave, and laser frequencies—are provided by the NBS Radio Standards Laboratory in Boulder, Colo. The laboratory conducts basic and applied research leading to standards for all important radio quantities (such as power, pulse quantities, attenuation, and noise), standards of frequency and time, and calibration and broadcast services which transmit these standards to industrial and Government laboratories. The Laboratory also uses its unique competence to measure selected atomic and bulk properties of matter and to improve the determination of fundamental physical constants.

High-Frequency Electrical Standards

International Comparison of Radio-Frequency Standards.—NBS is the supervisory laboratory for an international intercomparison of power standards at 3 GHz. Transfer standards have been furnished by Canada, USSR, Japan, and the United States. The transfer standards will be compared with the primary standards in each participating country, in turn. Measurements on the standards were completed at NBS and shipped to the next country, Canada. Results obtained in each laboratory will be reported directly to the International Bureau of Weights and Measures (BIPM) in Sèvres, France. The BIPM will issue a final report when all results have been received.

Radio-Frequency Voltmeter/Comparator.—A new, wide-band rf voltmeter/comparator has been developed for the frequency range d-c to 1 GHz. The device employs matched hot-carrier diodes in a dual-channel 50-ohm coaxial configuration. Power extraction from the signals being measured is negligible, and the coaxial line sections are impedance compensated to maintain a voltage standing wave ratio of 1.02 or less. The uncertainty in the voltage measurement is 3 percent or less from 0.5 to 15 V peak. Other applications include (a) measurement of differential rf voltage, (b) frequency-independent detector to 1 GHz, and (c) rf voltage comparator monitor of very high resolution.

Improvement in Coaxial Attentuation Measurement.—An automatic hydraulic servo system has been developed to control the displacement of the piston in a waveguide-below-cutoff attenuator. The

system enables the piston to be positioned with an uncertainty no greater than 10^{-6} mm. This precision is almost two orders of magnitude better than previous methods and results in a similar improvement in the measurement of attenuation.

High-Frequency Impedance Standards

RF Admittance Measurements.—An informal comparison of admittance standards has been completed by the Radio Standards Laboratory and the Ministery of Aviation in Great Britain. Three capacitors and four conductances were measured at a frequency of 5 MHz. The conductance values obtained agreed to within 0.25 percent, and the capacitance values to within 0.03 percent.

Radio Standards Comparators.—Under contract with the U.S. Air Force, the Radio Standards Laboratory is constructing a comparator for monitoring the calibration of standards of radio-frequency current, voltage, power, and impedance. Intended for use at the Base Laboratory level, the comparator will enable the user to detect, with a high degree of certainty, a standard which has drifted beyond acceptable tolerance limits. The purpose of the comparator is to increase both the accuracy of calibration at the base level and the efficiency of the overall calibration program.

RF-DC Transfer Standards.—A first model of a newly designed rf-dc transfer standard for rf current measurements has been constructed and is being evaluated. It employs an ellipsoidal reflecting surface to focus infrared energy from a resistance heater to a receptor. The heater may be energized by rf or direct current. The receptor is a thermopile with a direct current output.

Inductive Voltage Dividers.—An experimental binary type rf voltage divider attenuator having 42 dB in seven 6-dB steps was compared with the NBS precision piston attenuator at 1 MHz. The divider and attenuator agreed within 0.003 dB per 6-dB step, which is less than the estimated uncertainty in the piston attenuator at 1 MHz.

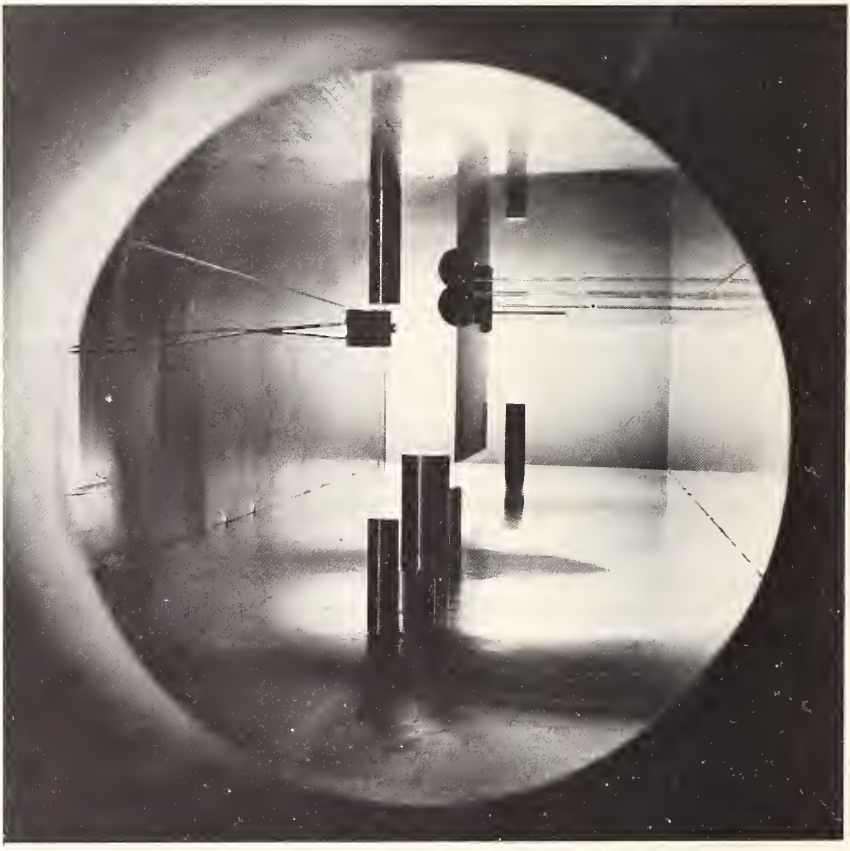
High-Frequency Calibration Services

Special Measurement Services.—There has been an increased demand for special measurement services as contrasted to calibrations of interlaboratory standards for basic quantities. In one major effort the U.S. Air Force was assisted in measurements for a large procurement of bolometer-coupler units. Also, a number of nonstandard calibrations, such as time delay calibrations for airline altimeters, were made.

Pulsed Quantities.—Additional pulsed power services were offered from 300 to 500 MHz. Pulse voltage, or base-band pulses, are now calibrated for nanosecond rise times, from 5 to 1000 volts.

Increased Immittance Services.—The large increases in accuracy announced last year have been extended to new frequencies, and to new values of capacitance, inductance, and resistance. NBS capabilities are now being better used in that new standards, which use the new precision connectors, are now being received for calibration. Uncertainties can be reduced up to 100 times on such standards.

Heat Flow.—A theoretical study was made of the dc-rf substitution error of a Wollaston wire bolometer power meter. The study resulted in the solution of the nonlinear differential equation which describes the heat flow by all significant transport mechanisms. Application of this theoretical study to millimeter wave equipment is expected to lead to the use of millimeter wave barretters as power standards.



To improve measurements of power at millimeter wave frequencies, this large-scale model of a Wallaston wire bolometer and related components was made approximately 100 times normal size. (In cross section the model is 16″ by 8″.)

Low Attenuation Measurements.—In the process of selecting lengths of waveguide of uniform specific resistance, microwave low-attenuation measurement capability has been extended to microbel precision. The stability necessary for such measurements was achieved through refinement of existing technology and inclusion of some innovations such as regulation of power output through servo-control of the klystron beam voltage. For eventual use in the system, and other systems, a rotary vane attenuator with microbel sensitivity and repeatability has been developed. An optical readout and improved rf shielding are features of the attenuator.

Reflection Coefficient Studies.—A computer program has been written to enable preparation of tables and graphs to facilitate calculation of reflection coefficients of quarter wavelength, short-circuited waveguide impedence standards. The tables will cover 38 standard sizes of waveguide and three sizes of 50-ohm coaxial line. This will enable anyone to construct his own standards of reflection coefficient for frequencies up through 325 GHz.

Small Attenuations of Waveguide Joints.—Data have been obtained on the small attenuations of waveguide joints versus frequency. Little or no data have previously been available on the frequency dependence of these losses, and these data should reveal more about their nature. The series and shunt losses of waveguide windows have been measured over the frequency range of the waveguide. The method which has been developed is especially convenient and accurate, but not quite as sensitive as cavity reasonance techniques.

Microwave Calibrations

Power Calibration Systems.—A new calibration service was established to fill a strongly needed measurement gap in the area of microwave power measurements for coaxial devices. The service provides continuous frequency coverage from 4 to 10 GHz for low-value bolometric power measurements on interlaboratory standards terminated with Type N coaxial connectors and from 4 to 8.5 GHz for the newer 14-mm precision coaxial connectors. The service is based on existing, recently developed microwave power calibration systems in rectangular waveguide and upon a waveguide-to-coax "adaptor" technique. Microwave power calibration systems were also developed for the measurement of low-value CW power in WR284 waveguide (2.6–3.95 GHz) utilizing the impedance variation method of power measurement and in WR42 waveguide (18.0–26.5 GHz) using the reflectometer method.

Calibration Accuracy of Bolometer Units.—A significant improvement in the calibration accuracy applied to bolometer units was

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achieved. This was accomplished by experimental and theoretical verification of the magnitude of an important error, usually referred to as the "rf-dc" substitution error, which must be accounted for in bolometric measurements. The reduction in the rf-dc substitution error by 0.7 percent permits an equivalent improvement in several calibration accuracies applied to both waveguide and coaxial bolometric power-measuring devices.

Reflection Coefficient Measurements.—Microwave calibration systems were developed for the measurement of reflection coefficient magnitudes in WR284 waveguide (2.6–3.95 GHz) and WR42 waveguide (18.0–26.5 GHz) using a modified reflectometer method of measurement. The development of the WR284 calibration system required the construction of an unusually large section of precision waveguide. Weighing more than 300 pounds, this component was constructed in NBS machine shops with specially-developed techniques and tolerances on the internal dimensions better than ± 100 microinches throughout its 24-inch length.

Phase Shift Calibration System.—A microwave phase shift calibration system has been developed for measurements on variable phase shifters in WR90 waveguide (8.2–12.4 GHz) utilizing a modulated subcarrier method of measurement. The estimated limits of the total measurement error for this new service are reported as approximately ± 0.25 degree including the error contribution from the reflection coefficient magnitude of the phase shifter being calibrated.

Electromagnetic Field Standards

Field-Strength Calibration.—A calibration service for field-strength and other precision receivers has been developed for the 1 to 10 GHz range. This new service includes calibration of the receiver as a two-terminal rf voltmeter, calibration of the signal attenuators, and calibration of the overall linearity of the receiver. The voltage measurements are made in terms of a coaxial power standard and are valid for rms CW measurements only. The attenuation and linearity measurements are made in terms of calibrated rotary vane attenuators. The calibration uncertainties vary from 2 to 10 percent, depending on frequency.

Antenna Field Measurements.—Significant progress has been made in the development of techniques for computing antenna characteristics (absolute gain and patterns) from near-zone data. In one NBS method, the radiation pattern of an antenna is expressed in terms of an angular spectrum of vector plane waves. The spectrum is obtained

from a two-dimensional, spatial Fourier-transform of the transverse components of the complex electric field in an "aperture plane." The antenna pattern can then be calculated for any distance beyond the aperture plane.

Dielectric and Magnetic Standards

High-Temperature Dielectrometer.—An accurate high-temperature (to 815 °C) microwave dielectric measurement service was activated and compared with previous results of five other laboratories. This service utilizes a measuring system developed in response to needs of industry for refined experimental techniques for evaluating high temperature dielectrics for radio-electronic applications. The technique uses a resonant cavity and a rod specimen.

Millimeter-Wave Dielectrometer.—The mm-wave interferometric dielectric measuring system was further evaluated and improved. Accuracy, defined in terms of "goodness" of fit of the theoretical to the experimental interference curve, is now of the order of ½ percent for the real part and 1 percent for the imaginary component.

Survey of Dielectric Measurements.—A critical survey and literature review of dielectric and magnetic measurements was undertaken from the viewpoint of radio-electronic and communications applications. Of special interest was the way in which these measurements depend upon the state of development of basic radio frequency—attenuation, impedance, etc.—and on how the measurements relate to the geometrical structure of the specimen and the electromagnetic environment. Dimensional gaging and small departures of the system from the form assumed in the ideal boundary value problem are often the limiting factors, rather than the electrical observations.

Narrow Linewidth Measurements.—A measuring service for the linewidth of single-crystal ferrimagnetic materials was activated. A nonresonant shorted waveguide method for the ferrimagnetic resonance linewidth is employed. Measurement of the linewidth was examined in detail by orienting the rf magnetic field relative to the static magnetic field on a given spherical specimen. It was concluded that the unloaded (intrinsic) linewidth can be correctly obtained from the measured linewidth and the magnetic resonator model of the specimen.

Tensor Permeability Measurement.—It was demonstrated that a cylindrical TM110 mode cavity is very satisfactory for measuring the tensor permeability of rod samples to as low as 1 GHz. It is possible to obtain good linewidth measurements on cylindrical samples with standard rectangular waveguide techniques normally used in studies of

ferrimagnetic resonance. A previously unreported ferrimagnetic absorption was also observed in this study.

Vibrating-sample Magnetometer.—Saturation magnetization is an important index or "figure of merit" of a ferrite for use in designing nonreciprocal microwave devices. The vibrating-sample magnetometer is a practical and accurate means for determining this quantity. Two of the most widely accepted methods for calibrating such magnetometers were examined in detail and the sources of error delineated. The study included nickel and pure iron as standard reference specimens.

THERMAL QUANTITIES

High-Temperature Heat Content Standard.—Standard materials for high-temperature heat content (enthalpy) measurements are essential for comparing different methods and apparatus and ensuring consistency of tables of standard reference data. The present standard material is aluminum oxide—synthetic sapphire—which melts around 2300 °K and is therefore an unsatisfactory standard material for higher temperatures. As part of a program to develop a standard material for higher temperatures, the enthalpy of tungsten has been measured up to 2700 °K with new apparatus developed at NBS. The precision of these measurements is higher than any previously reported.

Thermal Expansion Measurements at High Temperatures.—To meet the increased demands of high-temperature technology in both industry and defense, apparatus for measuring thermal expansion of solids at temperatures between 800 and 1600 °C has been developed. Length measurements made with this apparatus have an accuracy of 30–50 ppm, and are the most accurate available in this temperature range. Platinum, single crystal aluminum oxide, magnesium oxide, tantalum carbide, and pure tungsten are being investigated as possible reference standards for thermal expansion at high temperatures.

PHOTOMETRIC AND RADIOMETRIC QUANTITIES

Freezing Point Blackbodies as Primary Standards of Special Radiance.—Freezing-point blackbodies having efficiency of better than 0.999, and whose operating temperatures are known to better than one part in 50,000, were constructed and delivered to the Department of Defense Calibration Laboratories for use as primary standards of spectral radiance. Each furnace comprised a cavity, machined from high-purity graphite, immersed in a bath of liquid metal, contained in a crucible of high-purity graphite. As the metal freezes, the walls of the cavity are maintained at a very uniform temperature. High-

purity zinc, freezing point 692.745 °K, and tin, freezing point 505.093 °K, were used as the working metals. The crucible-cavity assembly was enclosed inside an insulated resistance heater, equipped with guard heaters to reduce conduction losses from the crucible. The duration of a freeze could be extended to several hours.

Spectral Irradiance Measurements.—Two specroradiometers, one based on a conventional prism monochromator and the other on a system employing a set of 36 narrow-band-pass interference filters, have been set up and independently used in the determination of the spectral irradiances of a number of sources commonly used in solar simulation. The wavelength range of measurement was 0.25 μm. The method of measurement for each system consists of comparing the spectral irradiance of the source under investigation to that of an NBS standard of spectral irradiance. The results obtained with each system on a number of continuous sources agree to about 1 percent, whereas the differences in the spectral irradiances obtained with the two setups on a number of line sources range up to several percent.

Spectral Radiance of the Graphite Arc.—Graphite arcs have long been employed as sources of spectral radiance, but their usefulness has been largely limited to wavelengths near 650 nanometers because of large differences or uncertainties in the results at other wavelengths. The spectral radiance of a commercially available low-current graphite arc has now been determined throughout most of the 210 to 850 nanometer region, with a standard deviation uncertainty varying from about 2 percent at the longer wavelength to 5 percent at the short. The investigation involved a direct determination of spectral radiance using a high accuracy spectroradiometer, which includes a stable high temperature blackbody and a photoelectric pyrometer for determining its temperature.

Laser Energy and Power Measurements.—The energy emitted by pulsed ruby lasers at 694.3 nm has been measured at both the Gaithersburg and Boulder NBS laboratories. At the former a calibration system was developed that uses phototubes and is based on the NBS blackbody traceable radiometric standard. This has been used to measure the output of a 1-joule laser. At the Boulder laboratory, calorimeters have been developed for use with lasers, and energies of 1 to 100 joules have been measured. Measurements by the two methods now agree to within 9 percent. Both methods are believed to have considerably higher pecisions—about one percent. Efforts are continuing to refine the techniques, determine an accurate value, and establish instruments that may serve as the basis for a national standard of laser energy.

Laser Beams Measured Using NBS Lamp Standards.—Two helium-neon cw laser beams, one of 0.83 milliwatt and one of 60 milliwatts, have been measured successfully on the setup normally used for the calibration of NBS lamp standards of spectral irradiance. No adverse effects, due to either the monochromaticity or the structured pattern of the laser beam, were present in the results.

Photo- and Cathodoluminescence Studies.—Relative spectral-energy emission characteristics and buildup and decay characteristics have been measured for most of the NBS standard phosphor samples by using ultraviolet excitation at either 253.7 nm or 365.0 nm. The time response of the zinc sulfide type phosphors was found to be a function of the magnitude of the excitation pulse used. A depressed cathode, oil-pumped, demountable system is being established to be used for measuring cathodoluminescence properties of phosphor powders and screens. A study of the coulomb aging mechanism of cathodoluminescence materials is also planned.

Calibration of Fluorescent Lamps.—Fluorescent lamps are now being calibrated for lumen output and spectral power distribution by direct comparsion, wavelength by wavelength, with incandescent lumen and color-temperature standards. This will make possible the issuance of fluorescent-lamp reference standards of known spectral distribution as well as known luminous flux and chromaticity coorinates.

New Low Spherical-Candlepower Standards.—A development has recently been completed on new low spherical-candlepower standards to extend downward the currently available luminous flux range and to supplement or replace the present low spherical-candlepower standard. The new standard are of four wattages, with spherical candlepowers about 0.34, 0.15, 0.05, and 0.03 candela at 5 volts. The standard lamps were developed primarily for the aerospace industry because many lamps of low light output are used in aerospace vehicle cockpit illuminated displays. A need for the new standards has also been expressed by the computer industry.

Artificial Star Source.—At the request of the National Aeronautics and Space Administration, a prototype of a low-intensity, uncollimated light source was developed as a standard for calibrating star-tracking equipment. Light from this source simulates the illuminance and "color temperature" of a visual second magnitude type AO star. The illuminance from a second magnitude star is 3.1×10^{-8} footcandle and the "color temperature" of a type AQ star has been defined as 10,700 °K. This standard has been used to calibrate a group of similar units constructed by NASA for use in the field.

Solar Radiation Measurements.—A program for developing and testing instrumentation which will measure the incoming ultraviolet solar irradiance on a horizontal surface has been completed. Two nearly identical photoelectric-filter spectroradiometers consisting of nine narrow-band- and one wide-band-pass interference filters covering the wavelength range 300 mm to 400 mm were constructed and simutaneous measurements were made at two locations, one having an atmosphere characteristic of a high degree of air pollution and the other having an atmosphere relatively free of air pollutants. A series of measurements at the two locations was made over a period of a few days during the four seasons of the year. The instrumentation will be turned over to the U.S. Public Health Service, which will continue the ultraviolet solar radiation measurements in connection with their overall air pollution program.

Systematic Notation for Reflection and Transmission.—The general concepts underlying measurements of the effects of objects on the propagation of light and other forms of radiant energy have been analyzed and systematized. The theory of the measurement of reflection and transmission characteristics has been unified and generalized to include combinations of these processes and such related processes as fluorescence. Concepts, terms, and symbols have been selected, with due regard to existing usage and standards. A systematic notation, based on established mathematical conventions, was developed to specify any of the infinite variety of geometrical arrangements and spectral conditions which might occur in practical applications. Eighteen classes of reflectance measurements have been identified and the mathematical interrelations among them have been published. This generalized treatment serves as a basis for unifying the concepts and terminology related to this kind of measurement in photometry, colorimetry, photography, and the graphic arts, where considerable divergence in usage has been apparent.

Standard Symbols in Radiometry and Photometry.—Members of the NBS staff directed efforts that led to the publication of USA Standard for Letter Symbols for Illuminating Engineering. This Standard is of exceptional importance because it contains for the first time a set of symbols for basic terms and units in the fields of radiation and light that has received international acceptance. These symbols were developed and agreed upon by committees of the International Electrotechnical Commission, the International Commission on Illumination, the International Organization for Standardization, and the SUN Commission of the International Union of Pure and Applied Physics.

Laser Source Integrating Sphere.—An integrating sphere was built to measure the spectral, directional-hemispherical reflectance at sample temperatures up to 2500 °K. To improve the signal to noise ratio a He-

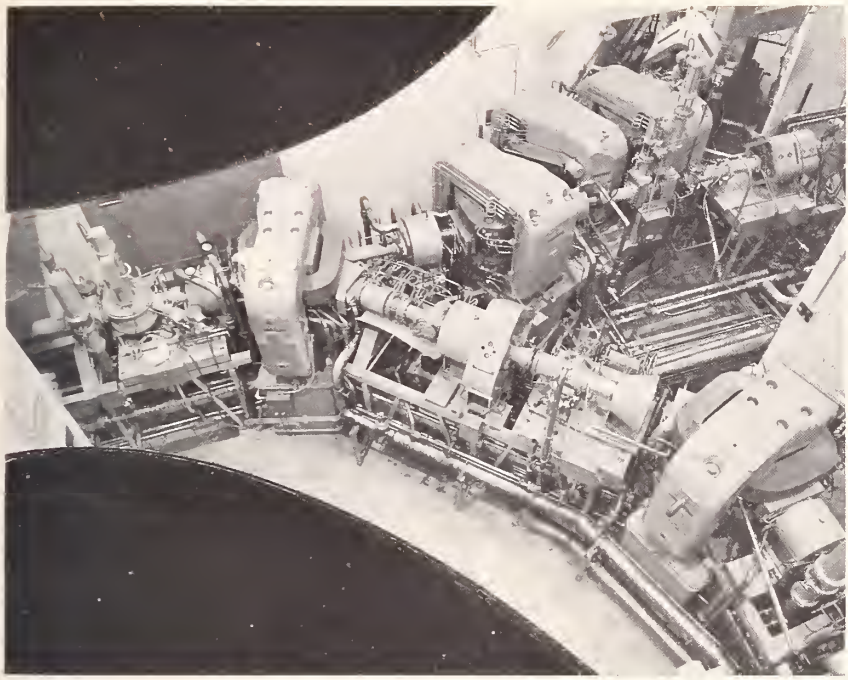
Ne laser was used as a source. A two-detector amplification system automatically corrected for power variations of the laser. An error analysis showed that the accuracy of the measurement is better than 1 percent. The error analysis was verified by an experimental investigation, using calibrated mirrors as standards. The instrument measures high-temperature reflectance data with an accuracy unobtainable with any instrument that measures emittance directly.

Optical Test Patterns.—Modern methods of testing optical and photographic systems rely heavily on the analysis of results obtained by imaging sinusoidal patterns of varying spatial frequency. The production of high-quality sinusoidal patterns for test purposes is not easy, nor is the quality evaluation of test patterns. To meet a specific Government need for such test patterns, a series of photographic patterns was produced. The photographs vary sinusoidally in transmittance and produce the desired pattern when placed on a diffuse illuminator. The optical density was measured with an automated microdensitometer, and computerized reduction produced tabular and graphic data for each pattern. The uniformity, modulation contrast, mean density, and wave form were computed automatically and shown to be within close tolerance.

New Refractive Index Technique.—A need arose for a precise measurement of the refractive index for both polarizations of a cuboid ruby crystal. Since the shape could not be altered to make a prism, the usual minimum-deviation method could not be used. The crystal was adhered to a prism of known index with a thin liquid film and light was passed through the crystal and prism. The crystal produced two wave fronts and by measurement and ray-tracing computations the two indexes were determined within 3×10^{-5}.

IONIZING RADIATIONS

Linear Accelerator.—The beam-handling system for the NBS linac was accepted from the contractor on July 2, 1966, and direct connection of the linac and beam-handling system was completed in the fall of 1966. Routine scheduling of accelerator time for experiments was begun early in January 1967, and a total of approximately 700 hours of beam on-time for experiments was provided in the remainder of the fiscal year. During this period of time all experimental programs prepared to use the accelerator were brought into operation to the point where they are now taking, or are about to take, meaningful data. These include programs in electron scattering, photoneutron production, photoproton production, measurement of neutron total absorption cross sections, studies in beam monitoring, programs in activation analysis, and production of radioactive sources for materials studies using Mössbauer sources and for studies of photonuclear reactions.



The NBS linac magnet room houses a system of magnets and collimators which refine the energy spread of the linac beam to less than 0.1 percent and steer it into one of three measurement rooms.

Positron Source.—Final beam tests were made on a converter target which utilizes the pair production cross section to convert a high-intensity electron beam into a source of positrons. The converter is designed to be used with the maximum average current obtainable from the NBS linac. It was successfully operated with average beam currents up to 0.17 mA, the highest presently available from the linac.

The 1.5-MeV Dynamitron.—The dynamitron has been successfully employed for experiments requiring both high and low current electron beams over its entire energy range from 0.2 to 1.5 MeV. For example, in nuclear excitation experiments where a high bremsstrahlung flux is required, a gold target was exposed to beam currents up to 5 milliamperes; however, in the measurements of the response of silicon solid state detectors to monoenergetic electrons where a low flux of electrons is desired, beam currents of 10^{-9} amperes were elastically scattered from a very thin gold target. The energy of the machine has been calibrated to better than ± 2 percent.

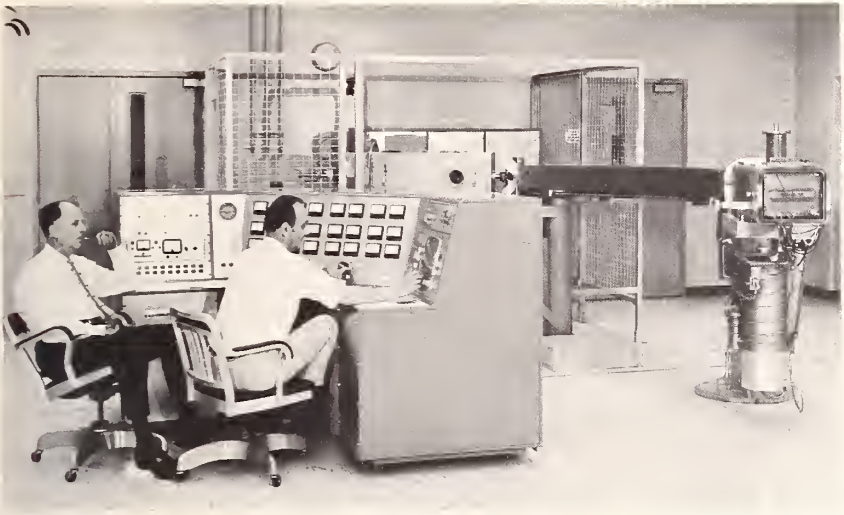
4-MeV Accelerator.—A momentum analysis system has been installed on the NBS 4-MeV Van de Graaff accelerator. This system pro-

vides a momentum analyzed beam of electrons with a resolution of approximately 0.2 percent at 3.0 MeV. In addition, a beam deflection magnet has also been installed to provide more flexibility in setting up experiments. There are now nine separate ports which may be used for experimental setups. At the present time the voltage regulating circuits are being updated to provide voltage stability compatible with the high resolution now obtainable with the magnet system mentioned above.

X- and Gamma-Ray Calibrations.—The new facilities for cobalt 60 and cesium 137 gamma-ray calibrations have been completed and provide exposure-rate ranges of from several thousand R/hr down to a few mR/hr. These gamma-beam facilities allow calibrations to be performed on a wide range of radiation instruments. The gamma-ray and x-ray facilities were used for the calibration and evaluation of about 70 instruments. In addition to the instrument calibrations, 37 small gamma-ray sources were calibrated, as well as several large cesium 137 calibrator units.

Measurement of Electron Beam Energy and Current.—A simple apparatus has been developed which permits the simultaneous measurement of electron energy and current of an accelerator electron beam. This measurement is accomplished with negligible interference of the beam during the continuous operation of the accelerator and applies to electron energies greater than 50 keV. The apparatus consists of a thin aluminum foil which intercepts the beam with a negligible energy loss (less than 1 kilovolt), and two cylindrical aluminum electrodes which are positioned respectively on the incident and exit sides of the foil with axes normal to the foil surface and coincident with the beam direction. When an electron beam passes through this system, the electron energy can be determined from the ratio of the incident to the exit electrode currents, and the incident electron current can be determined from the incident electrode current.

Radiochromic Dye Dosimetry.—New work with radiochromic dyes has shown these systems to be very promising for the accurate measurement of large radiation doses. The dye formation is measurable photometrically with precision limits of the order of one percent. The systems are highly versatile in that they can be used in liquid, vapor, powder, gel, or thin-film form. Current research for the Atomic Energy Commission is focused on developing liquid cells as measurement standards for measuring x- and gamma-ray exposures from 10^3 to 10^8 roentgens. Another project for NASA has provided a convenient device for beam profile evaluation.



This electromagnetic isotope separator was recently installed in the NBS Radiation Physics Laboratory for rapid preparation of highly pure, thin, mass-identified sources of stable and radioactive isotopes.

Photographic Dosimetry.—New techniques were developed for changing and improving the energy dependence of the response of radiographic emulsions. These techniques employ special chemical treatments and photographic processing methods involving physical and localized development of the exposed silver halide emulsions. The energy dependence of some emulsions has been reduced as much as threefold.

Radioactivity Standards.—In fiscal year 1967, 498 radioactivity standards were sold, and 39 calibrations performed. Two new radioactivity standards were produced: cobalt 60 in the form of a gamma-ray point-source, and mercury 197 in solution form. The following eight radioactivity standards were reissued with the same or better accuracies than previous issues: polonium 210; americum 241; solution standards of sodium 22 and iodine 125; point-source standards of yttrium 88; and point-source and solution standards of niobium 95 (with an accuracy of ± 1.5 percent and ± 1.2 percent, respectively). A special system for de-emanation of liquid samples containing radium 226 and subsequent counting of liberated radon has been installed.

PHYSICAL PROPERTIES

Approximately 50 percent of the activity within the Institute for Basic Standards involves the characterization of physical properties of well-defined substances. The rapid growth of the physical sciences

has provided scientists with many new techniques for measuring "old" physical properties and has made accessible many new ones. With new techniques it has been possible to increase the precision of measurement, provide the scientific community with a greater range of reference data, and characterize certain processes more fully. Examples of these activities, drawn from current work, are given below.

Nuclear Properties

Solid-State Beta-Ray Spectrometer.—A spectrometer has been constructed for analyzing electron energy distributions with a very high efficiency and with a resolution comparable to the much lower efficiency magnetic lens spectrometers. The spectrometer employs two cooled lithium-drifted silicon detectors of better than 5 keV resolution which are operated in a 4π geometry or in a 2π geometry with a selection of events where all of the electron's energy is deposited in one detector. Time coincidence with associated gamma rays selects the electron spectrum of interest.

The Nuclear Three-Body Problem.—A calculation of the photodisintegration of ^{3}H and ^{3}He has been made using approximate ground-state wave functions based upon two-body effective range theory. The results are in fair agreement with experiment and considerably better than previous calibrations. A new calculation has been started using wave functions derived from a separable nucleon potential. These wave functions have been successfully applied to neutron-deuteron scattering.

Radioactivity Studies.—Residual activity studies of the monoisotopic nuclides bismuth and praseodymium after bombardment with the linac electron beam have resulted in measurements of multi-neutron deficient daughter products in which as many ten neutrons have been removed. The data can be represented by a simple power law relating daughter product yield to the number of nucleons emitted. This power law has been used to predict the yield of any specific daughter product, the total decay gamma-ray rate, or the total gamma-ray dose to be expected from any target material, including composite materials, for arbitrary bombardment time and arbitrary times after bombardment. Experimental tests of these predictions indicate that they are sufficiently accurate for radiation protection purposes. The calculations also indicate a number of previously unobserved radioactive nuclei with reasonable half-lives, far off the stable mass curve, which should be produced in significant quantities by electron bombardment.

Electron Scattering.—The apparatus for elastic and inelastic high-energy electron scattering with the NBS linac has been brought into operation. An experiment to measure the inelastic scattering cross

sections for exciting nuclear levels in ^{12}C at 4.4, 7.6, 9.6, 10.8, 15.1, and 16.1 MeV was performed at three angles and at momentum transfers up to 220 MeV/c. Analysis of this data should yield strengths and transition radii for both longitudinal and transverse excitations of these levels. A new multi-channel detector system containing twelve semiconductor detectors has been completed and is presently being installed. The new system should improve the experimental energy resolution by a factor of four (to 0.1 percent) with no loss of data-taking speed.

Heavy-Ion Spectrometer.—A large magnetic spectrometer for the spectroscopy of charged particles from electron- and photon-induced nuclear disintegration reactions has been constructed. The spectrometer magnet is a double-focusing, 120° wedge with a 45.6-cm radius of curvature. The energy resolution of the magnet at the central momentum orbit is better than 0.2 percent and the useful solid angle is 0.006 sr. (maximum solid angle is 0.01 sr.). When fully implemented with fifty 0.2 x 0.2 x 6 cm semiconductor radiation counters in the focal plane, the spectrometer will have a total energy acceptance interval of approximately 20 percent. The focal plane counters are lithium-drifted gold-surface barrier counters especially developed at NBS for the spectrometer. In use they are cooled to 77 °K to ensure fast and uniform response.

Cryostat for Neutron Cross Section Measurements.—A He^3 refrigerator with a perpendicularly mounted 55 kilogauss superconducting solenoid was completed and used to provide a large polarized holmium target. This equipment was shipped to the Proton Synchrocyclotron at the Atomic Energy Resarch Establishment, Harwell, England, for use in a joint project to determine the shape of the highly deformed holmium nucleus. These measurements were carried out using neutrons covering the entire energy range from 1 to 130 MeV. The low-energy neutron data are being analyzed in terms of the optical model of the nucleus, whereas the high-energy data are being compared to the black nucleus model.

Photonuclear Data Center.—The file of photonuclear data and its index have been maintained up to date with the current literature. On the average, new data are added to the files within less than three months of the publication date. New entries are being made to the file at the rate of about 140 per year. Data in the files were the basis for a series of lectures surveying a part of the field given at the Institut fur Theoretische Physik der Universitat Frankfurt/Main.

Atomic and Molecular Properties

Spectra of the Lanthanide Elements.—Knowledge of the electronic level structures of neutral promethium, cerium, thulium, and thorium has been expanded during the past year. Significant progress has also been made on the spectra of singly ionized holmium and thulium. An analysis is underway on the spectrum of neutral holmium, for which no levels are presently known.

Atomic Spectra in the Vacuum Ultraviolet Region.—Observation of the neutral silicon spectrum has been completed. One hundred and forty-one Si I wavelengths of high accuracy suitable for use as standards in the region 156–200 nm were obtained. Selected lines for neutral carbon, nitrogen and germanium and for singly ionized copper and silicon were measured. There are now about 500 wavelengths in the region below 200 nm with uncertainties of 0.0002 nm or less.

Lyman-Alpha Excitation.—The flux of Lyman-α photons (121.6 nm) excited by an electron beam of known intensity and energy has been measured in a high-vacuum apparatus. The excitation probability has been measured with a precision of better than one percent and an accuracy of the order of 2 percent. This process is the cause of one of the strongest solar radiations, but one observable only at rocket and satellite altitudes because of ionospheric absorption. Detailed interpretation of observations of solar radiation will be aided by knowledge of this inelastic atom-electron collision process.

Profiles of Resonances in Atomic Continua.—Using the NBS 180-Mev electron synchrotron as a background source for atomic absorption spectroscopy, the absorption profiles of all the prominent resonances in the continua of the noble gases have now been obtained. The resonances are caused by short-lived high-energy states involving inner electron excitation, or the excitation of two electrons simultaneously. The data were obtained on an NBS-constructed high-resolution scanning monochromator of the grazing incidence type, and data collection and reduction have been automated. All of the prominent resonances in helium through xenon have been studied, and data are now being reduced and made available to theorists.

Theoretical Studies.—A simple quantum-mechanical model for a maser or laser was extended to include correlation between radiating atoms and the field, and also between different atoms. Problems arising in the solution of the resulting set of nine coupled differential equations have now been overcome. The results indicate the accuracy of the semi-classical approximation used in the simpler theory in a way distinct from that used previously. An unexpected result of the above analysis was the integrated noise behavior of the maser. This led to a

certain amount of study of maser noise by simpler classical methods and of noise theory in general.

Solar Astrophysics.—Active collaboration in solar astrophysics between the NBS Joint Institute for Laboratory Astrophysics and the Sacramento Peak Observatory is providing a detailed study of the solar atmosphere, especially its nonhomogeneous structure, with special attention to aerodynamic motions. A new model for the structure of the sunspot is being developed. Particular emphasis has been given to the relation between convective motions and magnetic fields in the penumbra and its relation to the structure of the umbra.

Structure in Gas Laser Transitions.—In gas lasers a spectrum line whose upper state is the lower state of the laser transition may contain a structure due to the laser action. This structure has been observed on the 610-nm neon line emitted spontaneously in a 1.15-μm helium-neon laser. In addition, measurements have been made of the dependence of frenquency on gas pressure in the $3s_2$—$2p_4$ (632.8 nm in air) transition in a helium-neon laser.

Molecular Gas Lasers.—Progress has been made in understanding the fundamental processes which occur in several molecular gas lasers. By making use of accurate molecular energy levels determined from high-resolution infrared absorption measurements, it has been possible to explain laser action in ammonia, carbon disulfide, and cyanide-type compounds. In particular, laser action in the so-called "CN" laser has been shown to result from hydrogen cyanide, HCN. In terms of this discovery, a far more satisfactory explanation of the far-infrared "CN" laser has been achieved.

Spectrum of the Free Radical NCO.—The spectrum of the free radical NCO has been produced both by the vacuum ultraviolet photolysis of matrix-isolated HNCO and by the reaction of photolytically produced carbon atoms with NO in a matrix environment. The presence of this species in both systems has been confirmed by the observation of the two electronic transitions of NCO previously detected in studies of the flash photolysis of gaseous HNCO. The three fundamental vibrations of ground-state NCO have been observed and are in excellent agreement with the values deduced from the flash photolysis studies.

Vibrational and Rotational Spectra of Simple Molecules.—Infrared and microwave spectra have been studied in a number of molecules which have features of special interest. Definitive molecular structures have been determined for two boron compounds, diborane (B_2H_6) and difluoroborine (BHF_2). Centrifugal distortion in the transient frag-

ment CF_2 has been analyzed. The microwave spectrum of silocyclobutane (CH_8Si), a newly discovered molecule with some novel features, was also analyzed.

Matrix Isolation of Alkali Salts.—Infrared measurement on the components of the vapors of certain high-temperature refractory materials have been carried out by use of the matrix isolation technique. The vapors in equilibrium with lithium fluoride (LiF), cesium hydroxide (CsOH), and rubidium hydroxide (RbOH) have been investigated, using this method. Vibrational frequencies and molecular geometry have been determined for these hydroxides and a dimer of lithium fluoride. The understanding of the structure of these hydroxides has been advanced considerably by studies of their microwave spectra.

Ionization Energies and Appearance Potentials.—A compilation of ionization and appearance potentials is in the final stages of preparation. The values have been abstracted from more than 1000 articles published in the period between 1955 and midsummer of 1966. They are combined with thermochemical data to yield heats of formation for most of the ionic species and for a limited number of neutral molecules as well.

Photodetachment of Negative Ions.—The photodetachment of SH^- and SD^- has been studied in detail. These ions are of astrophysical interest and also of interest as standard diatomic negative ions in the laboratory. The threshold energy has been determined to be 2.31 eV. The threshold behavior of the cross section has been studied carefully, and a modified parabolic behavior is consistent with the data. However, since the rotational temperature of the negative ions is not known by direct measurement, the extent of the "modification" cannot be precisely determined. The size of the modification was expected to depend on the polarizability, and the observed size relative to that for I^- is consistent with this interpretation.

Electron Scattering From Helium.—Both elastic and inelastic scattering from helium as a function of scattering angle have been measured for electron energies from 100 to 400 eV. Absolute differential cross sections derived from these measurements have been particularly useful in determining the range of validity of the Born and Ochkur approximations. For excitation of the 2^1P state in helium, the Born approximation is found to be good down to energies of about 100 eV, while for 2^1S excitation there are deviations from the Born approximations even at 400 eV. Excitation of the 2^3S state, which is possible only by electron exchange, shows very large deviations from the predictions of the Ochkur approximation, and also of the Born-Oppen-

heimer and Rudge-Ochkur approximations. Differential cross sections for elastic scattering show large deviations from the Born approximation at small scattering angles, but agree very well for large scattering angles.

Negative Ion Studies in Crossed Beams.—The first experimental measurements of the process through which negative hydrogen ions are destroyed in collision with electrons have been completed. This pioneering crossed-charge beam experiment introduces a new approach to the determination of atomic properties of this kind. The results have settled a controversy in theoretical physics, since prior predictions of this collision cross section were inconsistent with one another by a factor of 1000.

Electron-Molecule Collisions.—Studies have been made on the production of energetic ions in nitrogen and on the dissociative ionization of hydrogen and deuterium when bombarded by electrons. These results give information about repulsive molecular potential curves which is almost impossible to obtain in any other way. This is particularly important because of the great interest in low energy heavy particle collisions.

Electron Density of Free Electrons in the Mesosphere.—An analysis has been made of the molecular reaction rates which determine the density of free electrons which will exist under varying circumstances in the earth's atmosphere at about 40 miles altitude. The new theory successfully explains both natural causes of interruptions to radio communications in the Artic and the unusual behavior of atmosphere ionization caused by nuclear detonations in the atmosphere. This work depends upon a large number of successful measurements of molecular properties, some performed at NBS and many of the most important ones made in the Environmental Science Services Administration laboratories at Boulder, Colo. The work has had significant impact on the research and development programs of the Department of Defense in the area of ballistic missile defense.

Radio Plasma.—During the past year the noise emitted in the microwave range by the brush cathode plasma immersed in a uniform magnetic field has been studied both experimentally and theoretically. Particular attention has been paid to the radiation emitted parallel with the magnetic field. A theoretical model has been developed that seems to account very well for the relative and absolute intensities of the observed circularly-polarized noise spectrum. Other cathode designs, with cathodes made of graphite, have been tried and show improvements in several respects over the brush cathode, particularly when operated in magnetic fields with high power densities.

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Solid State Properties

Electron Scattering in Aluminum Oxide Films.—Measurements have been completed of the energy loss spectra of 20-keV electrons transmitted through thin films of Al_2O_3. Two types of Al_2O_3 were used: films of the γ-phase and amorphous films prepared by anodization. Slightly different structure was found in the energy loss spectra for the two forms of Al_2O_3, both for excitations involving the valence electrons and those involving electrons from the Al L-shell. Values of oscillator strengths and electron-scattering cross sections have been derived from the observed intensities.

Electron Quantum Interaction.—An electron-microscope technique has been evolved for "super-Tolansky" topographic imaging of thin, fractured diamond plates and wedges. Making use of high numerical values of diffraction contrast in the dense lattice, it provides brilliant stereo-topographic detail of submicron fracture surfaces. Cleavage and fracture of hard crystalline materials may be studied easily to a resolution of 3 nm in full stereographic detail.

Spin-Phonon Interactions.—The interaction between spins and phonons was examined using nuclear magnetic resonances as a probe. This research led to the recently announced measurement of the hexadecapole moment of indium in InAs. The hexadecapole transition had been previously predicted but not observed. Interactions between phonons and the nuclear spin system were investigated in both magnetic and nonmagnetic crystals.

Self-Supporting Metal Films Produced.—A method of producing self-supporting aluminum films has been developed. The process involves the evaporation of sodium chloride onto a suitable substrate, such as quartz, and the subsequent deposition of aluminum over the NaCl. After immersion in water the salt dissolves leaving the film floating on the surface. Films as thin as 6 nm have been made which are very nearly pin-hole free. Such films pass ultraviolet light while reflecting longer wavelengths.

Thermodynamics and Transport Properties

High-Temperature Properties of Inorganic Salts.—In order to meet an increasing need for accurate data on the high-temperature properties of inorganic salts, the critical compilation of thermodynamic and chemical kinetic properties of these compounds has been started. A monograph on sulfates was published during the year and a similar work on carbonates is in preparation. Each monograph in the planned series will be devoted to salts of a simple anion and will give informa-

tion particularly relevant to the high-temperature stability of the compounds.

Ideal-Gas Thermal Functions for Ammonia.—Tables of thermodynamic properties have been computed for ammonia as an ideal gas in the temperature range from 50 to 4000°K. These allow for the highly anharmonic inversion spectrum of the ground state and the nearly planar molecular configuration in higher vibrational levels. The results for NH_3 approach in accuracy those obtained for the relatively simpler water molecule. They represent a significant improvement over thermodynamic properties previously available. The extension of the treatment of the ideal gas to the real gas is now in progress.

Equation of State of Gases in the Critical Region.—At the critical point many thermodynamic properties of compressed gases show anomalous behavior. The critical anomalies in various thermodynamic properties can be interrelated by so-called scaling laws. A detailed study of experimental data has revealed that a recently proposed scaling law equation of state describes the thermodynamic behavior of the gases CO_2, SF_6, N_2O, $CCIF_3$, Xe, Ar in the critical region very well. This discovery opens the possibility for predicting and correlating thermodynamic properties of gases in the critical region.

Heat of Combustion in an Adiabatic Rotating Bomb.—Calibration measurements using benzoic acid have been completed on a new adiabatic rotating bomb calorimeter. The bomb consists of layers of silver, stainless steel, and an inner lining of platinum. The temperature rise is measured by a capsule-type platinum resistance thermometer imbedded in the stainless steel layer of the bomb wall. The automatically controlled adiabatic shields maintain a temperature difference of 0.0002 °C with respect to the outer wall of the bomb at all times except for the first half minute of the combustion period. During this time, the difference rises to as much as 0.04° for a few seconds. For an experiment producing a 3-degree temperature rise, the net error introduced by this departure from control is less than 2 ppm.

Flame Calorimetry of Fluorine Compounds.—Fluorine and its reactive gaseous compounds form an important group of oxidizers in the aerospace propellant field. New apparatus and procedures were developed for conducting reactions of these substances with other gases in a constant pressure flame, in such a way that the heats of reaction could be measured using high-precision calorimetric equipment and techniques. Gaseous and liquid reaction products are retained in an aqueous solution inside the calorimeter so that they are in a well defined thermodynamic state, and are readily analyzed to allow an accounting to be made of all reaction products. In a recently completed

study of the heat of formation of oxygen difluoride (OF_2), the heats of reactions of OF_2, F_2, and O_2 with hydrogen were measured. The results were precise to a few hundredths of a percent and are believed to be accurate to better than 0.1 percent. They demonstrate the possibility of obtaining accurate thermochemical data for other extremely reactive fluorine-containing oxidizers.

Transition Region Heat Capacity and Entropy of Ni-Ti.—The heat capacity of the intermetallic compound nickel-titanium has been measured through the solid-solid transition region slightly above room temperature. These measurements are important to understanding the nature of the transition, which has the odd property that a coil formed of nickel-titanium wire will straighten out to its original form when heated through the transition. The measurements establish the higher-order nature of the transition and a lower limit for the entropy of transition.

High-Speed Techniques for High-Temperature Studies.—High-speed (millisecond and microsecond time-resolution) electrical pulse techniques are being employed for generating high temperatures (above 2000 °K) in electrically conducting substances. Recent experiments indicate that such dynamic methods provide excellent means for the study of behavior of matter at high temperatures. A unique dynamic high-speed thermodynamic measurement system has been developed which has the capability of measuring simultaneously several thermodynamic and transport properties. In the initial experiments measurements have been made on the specific heat, electrical resistivity, and thermal emittance of refractory metals and alloys up to their melting points.

Glass Electrodes for Molten Salts.—In research relevant to the development of cation-selective glass electrodes usable in molten salts, it was found that fused silica exhibits such selectivity for sodium and lithium ions at concentrations as low as 10^{-3} mole percent. The selectivity for potassium and cesium in this concentration range is negligible, and melts may therefore be analyzed for the former ions in the presence of the latter up to 1000 °C.

Shock Wave Propagation in a Solid.—The properties of a crystalline solid compressed to millions of atmospheres by the passage of a strong shock wave are being studied by means of computer experiments from an atomistic, lattice dynamical viewpoint. The main objective is to investigate the role of interatomic forces on the propagation of shock waves, and to determine the equation of state of highly-stressed solid under high-temperature conditions. This information is needed for the proper interpretation of a variety of high pressure

phenomena ranging from laboratory impact experiments to the shock-induced metamorphism in rocks found in meteoritic impact craters on the earth's (and possibly lunar) surface.

Analysis of Trace Components in Gas Mixtures.—A rapid, simple method has been developed for the determination of isotopic ratios in volatile compounds, in research sponsored by the Arms Control and Disarmament Agency. It combines gas chromatography (for separations of components) and differential gas density analysis. After chromatographic purification the difference in density of normal CO_2 and a mixture of normal CO_2 and $^{13}CO_2$ (produced by burning labeled compounds) was easily detected in a differential gas density balance. The sensitivity of the method permitted a difference in molecular weight of 2×10^{-4} g/mole to be determined. The method is readily adaptable to other isotope ratio analyses and to the measurement of gas imperfections.

Chemical Kinetics

Fragmentation of "Superexcited" Molecules.—The decomposition of "superexcited" hydrocarbon molecules (neutral excited molecules above the ionization threshold such as ethylene, propane, butane, and isobutane) has been studied, using as the excitation source monochromatic radiation of high spectral purity from krypton (10.0 eV) and argon (11.6–11.8 eV) resonance lamps. Ionic processes can be characterized by known ion-molecule reactions. It is found that the "superexcited" molecules undergo the same fragmentation processes as do molecules excited to lower electronic levels with carbon-carbon and carbon-hydrogen cleavage processes becoming more important relative to molecular elimination processes. In addition, the measurement of saturation currents in these experiments has permitted the determination of the relative importance of neutral excitation versus ionization for these molecules.

Absolute Reaction Rates of Atoms.—A combination of the technique of flash photolysis, absorption of Lyman-alpha radiation by hydrogen, and measurement of the subsequent Lyman-alpha fluorescence, was used to measure the absolute rate constants for the reaction of hydrogen atoms with several olefins at room temperature. The method distinguishes hydrogen atoms from deuterium atoms and can be used to measure either. The experimental method is, in principle, generally applicable to the study of reactions of other atoms.

Thermal Decomposition of Olefins.—The pyrolysis of 4,4-dimethylpentene-1 was studied at 1000–1100 °K by a shock compression technique. The rate constant for the main bond breaking step has been measured as a function of temperature. The results lead to an estimate

of 12 kcal/mole for the resonance energy of the allyl radical. Rate parameters were estimated from this data for the thermal decomposition of butene-1, 4-methylpentene-1, and 1,5-hexadiene. These estimates agree with published experimental values. Present experiments indicate that determination of a limited number of rates for pyrolysis can serve as a basis for prediction of rate parameters for the decomposition of most simple hydrocarbons.

Surface Properties

Anomalous Work Function of (110) Tungsten.—Measurements of field emission from the (110) plane of tungsten single crystals (in the absence of contaminants) have been shown to result in anomalous work function values. It was suspected that temporally and spatially correlated electron emission might be responsible for the anomaly. This hypothesis was investigated by precise measurement of the pulse height distribution of an electron multiplier detecting field emission from the (110) plane. It was shown that less than 2 percent of the emitted electrons are correlated, indicating that the anomalous emission must be due to some other mechanism.

Photoelectron Emission From Tungsten in the Vacuum Ultraviolet.—An ultra-high-vacuum facility for the study of optical and photoelectric properties of metals in the vacuum ultraviolet has been put into operation. The facility is unique in attaining vacua in the region 1.333×10^{-1} N/m^2 (10^{-10} torr) while utilizing windowless optics, a technique required for photon energies greater than 11.5 eV. In the range 7.7 to 21.2 eV, initial measurements showed that oxygen and nitrogen produced marked changes in the photoelectron yield from polycrystalline tungsten for coverages of considerably less than one monolayer. These changes in yield are being related to changes in the work function and the onset of photoemission from the contaminating layer.

Desorption Lifetime of Cl^- *and* I^- *on Molybdenum.*—Desorption lifetime measurements for cloride and iodide ions from polycrystalline molybdenum have been made with a modulated molecular beam mass spectrometer. The formation of negative ions on a metal surface is very inefficient and requires the development of very sensitive instrumentation. By using pulse techniques to process the signal from the mass spectrometer, reliable lifetime measurements were made possible. These measurements indicate that an electrostatic image force alone does not account for the energy necessary to desorb these negative ions from a clean molybdenum surface.

Diatomic Molecules Chemisorbed on Tungsten.—Studies of the interaction of low-energy electrons with chemisorbed diatomic molecules on tungsten surfaces have led to further understanding of surface binding in chemisorption. By using retarding-potential methods it has been possible to study the distribution of positive ions produced by electron impact, and in separate experiments to measure work function changes on chemisorption on single crystal wafers. In the case of carbon monoxide on tungsten, two distinct ion energy distribution peaks were observed and related to differences in electronic structure of two binding states on the surface. In the case of nitrogen on the (100) plane of tungsten, a linear relation between work function and coverage (as measured by flash desorption) indicated that depolarization effects between adsorbed species are small.

APPLIED MATHEMATICS

The Institute for Basic Standards conducts a program in applied mathematics and statistics to meet varied needs in the development of new measurement techniques and in the evaluation of the results of measurement. The level of the mathematics involved makes it essential to conduct fundamental mathematics research on a fairly broad scale.

Solution of the Tournament Problem.—New solutions were developed and published for the tournament problem. In high-precision calibrations one measures differences between nominally equal objects or group of objects and establishes a value for the individuals with reference to one or more standards. The solutions of the classical tournament problem, which calls for arranging individuals into teams of players so that a player is teamed the same number of times with each of the other players and also that each player is pitted equally often against each of the other players. provide balanced designs for scheduling the measurements.

Mathematical Modeling.—Substantial assistance was rendered to the simulation effort of the Department of Transportation's Northeast Corridor Transportation Project and useful mathematical methods were devised for the analysis and synthesis of possible advanced interurban transport systems. Mathematical models of transport market split were anaylzed. The reducibility of a class of optimal transport investment problems to shortest-path problems was established. Studies were made on a "best" network connecting prescribed points and on how to allocate "open" periods among traffic streams at a congestion point. Also, an effort was initiated to explore mathematical methods and models potentially useful in arms control analyses.

Numerical Analysis.—A method was developed for the exact solution of sets of linear equations with integral elements. The method has special value because in contrast to methods in general use, it is insensitive to the "condition" of the coefficient matrix and is impervious to the usual ills caused by roundoff and truncation errors. A new algorithm has been constructed for the computation of subdominant solutions of difference equations. Applications have been made to Bessel and other special functions, and a powerful error analysis has been developed and tested. Other programs included numerical solution of the collisionless Boltzmann equation governing rarified plasmas and development of a technique for expanding the solution into eigenfunctions.

Theories of Turbulence.—A fluid theory for plasma turbulence was developed which predicts the spectra of density and electrostatic field fluctuations. The predicted density spectrum is in agreement with experiments at NASA. Also, in the field of statistical mechanics of ionized gases a fluid theory was devised, on the basis of the Riemann equations, to investigate the eddy diffusivity. The theoretical results agreed with the empirical formula of Bohm, and helped clarify the nature of collisonless dissipation. A cascade theory of magnetohydrodynamic turbulence was developed, based on the decomposition of the velocity and magnetic field fluctuations into large and small eddies. The turbulent and magnetic spectra derived on the basis of this theoretical model clarify the well-known controversy about the shift between the two spectra in magnetohydrodynamic turbulence.

Surveillance of Standards.—A cooperative effort with the IBS Electrochemistry Section was undertaken to develop procedures for maintaining surveillance over groups of saturated standard cells. The principle of left-right balance as a means of eliminating certain systematic errors in measurement processes was implemented in several classes of calibration designs. These designs are applicable in other measurement areas.

Transient Thermal Stress.—An analysis and computer program were completed and published which determine the transient total stress in an elastic solid in the neighborhood of a surface on which a given transient two-dimensional heat flux is given.

Bolometer Substitution Error.—An approximate analysis and a computer program have been written which determine the substitution error in a bolometric power measurement in terms of the geometry circuit resistance, and the rf current profile. A nonlinear model for the heat flow is involved.

Ion Reaction and Diffusion Problems.—By analytical and computational methods, many factors affecting the interpretation of measurements in an ion reaction tube have been studied: neutral source configuration, ionic model distribution, axial and wall diffusion effects, multi-component reactions, velocity fields, axial pressure and temperature gradients, and the transient diffusion and transport of an ion sheet. Analysis and programming have been carried out to obtain time- and altitude-dependent equilibrium atmosphere ion densities for some models of the ion and neutral reactions.

TECHNICAL ASSISTANCE TO OTHERS

The Institute is a source of technical assistance and consultation to other Government agencies with problems in specialized areas of physical measurement and applied mathematics. Its sponsorship of the National Conference of Standards Laboratories permits joint study of management and operation techniques, and has led to a series of seminars on precision measurement. In cooperation with various technical societies, NBS also conducts conferences and symposia important to wide segments of science and industry.

Studies for Other Agencies

Back-Scatter Visibility Meter.—A prototype back-scatter visibility meter has been designed and constructed for the Bureau of Naval Weapons. The meter will test the feasibility of using instruments of this type aboard aircraft carriers. The instrument consists of a projector with a flashtube as a light source and a receiver that alternately receives flux which (a) is scattered backward from the beam of the projector, and (b) comes directly from the projector. The ratio of the two signals is determined and displayed. Thus the reading is not affected by changes in the output of the projector or sensitivity of the receiver.

Radioactive Contamination of Materials.—An extensive study of radioactive contaminants in chemical reagents and commercial materials is being carried out for the United States Atomic Energy Commission. The extent of this low-level contamination, its variations with time, its nature, and its dependence on manufacturing practices and geographical factors are being considered in order to allow for, or to correct for, the radioactive contaminants in these materials. Special techniques and highly sensitive counting instruments located in appropriate facilities are being used. A study on the transmission of beta particles emitted by "infinitely thick" sources was completed. The purpose of this investigation was to determine the maximum energy of beta particles emitted by low-level sources.

Standard Nuclear Instrument Module System.—The Standard Nuclear Instrument Module System, developed in conjunction with the AEC National Laboratories, is proving to be of increasing utility to nuclear research. Essentially the entire nuclear instrumentation field in this country, and an increasing number of laboratories and industries throughout the world, have adopted the system. It provides for interchangeability of nuclear instruments regardless of the laboratory or commercial concern that designed or produced them. Since the interchangeable modules can be inserted indiscriminately in standard bins, systems can be optimized and component modules reused in different system arrangements with complete flexibility and without the additional expenditures that stocking of incompatible equipment would entail.

International Comparisons.—The Bureau participated in the determination of environmental levels of tritium in water, carbon 14 in starch, and potassium 40 in feldspar. This study was performed for the United Nations International Atomic Energy Agency. NBS also participated in the International Bureau of Weights and Measures international comparison of cobalt 60, and in the second intercomparison of mercury 197 among pharmaceutical laboratories and national laboratories in the United States and Canada.

Strain-Measuring Standards for High-Temperature Use.—A pneumatic extensometer was designed and constructed for the U.S. Air Force Systems Command. This device will determine performance characteristics of strain-measuring devices used under field conditions. The efficient use of materials that will provide the lightest structure that can meet performance requirements with a reasonable factor of safety is especially important in spacecraft, missiles, and high-performance aircraft. These are structures that are exposed to severe environmental conditions, including high and rapidly changing temperatures. Measuring structural strains during prototype development and evaluation under actual or simulated use conditions is one of the best methods of insuring the safety and integrity of the final product.

Wave Studies.—Under sponsorship of the Office of Naval Research, studies are being made on wind-generated waves and tides and on internal waves in a density stratified liquid. A study of wind forces on a water surface is important for understanding the generation of water waves by wind and the formation of wind-generated tides. In these experiments regular trains of smooth waves were mechanically generated by an oscillating paddle at the upwind end of a wind-wave channel in which air is blown at speeds up to 10 meters per second in the direction of travel of the waves. Wind shear force on the wavy

A gas-cooled extensometer is assembled for tests in an oven capable of temperatures up to 1650° C. This apparatus is used to determine performance characteristics of strain measuring devices under field conditions.

surface and wave heights along the channel were determined for each wind speed and initial wave configuration. It was then possible to deduce information on energy transfer from wind to waves and on surface shear-stress coefficients as a function of wave shape.

Highway Culverts.—An investigation of the hydraulics of highway culverts, conducted over a period of several years at NBS under the sponsorship of the Bureau of Public Roads, has now been concluded. Investigation has shown that the water-carrying capacity of highway culverts can be substantially improved over that realized with commonly used types. The problem arises from the fact that the barrel of the culvert (the pipe of duct under the road) does not generally flow full even though the entrance may be fully submerged. Several factors influence these conditions, but the principal one is the shape of the entrance. Laboratory modelling experiments were directed toward a fundamental understanding of these factors, with the principal emphasis being placed on inlet shapes designed to promote fuller flow, and correspondingly greater carrying capacity for a given size and cost under the various conditions met in practice. It was found that by employing tapered inlet structures of simple and practical geometry the flow capacity of culverts having sufficient slope can be increased

from 50 to 75 percent above that obtained with commonly used entrance designs. These figures moreover, apply to flow under unfavorable conditions such as may occur in practice.

Conferences and Seminars

Precision and Accuracy in Measurement and Calibration.—In this 4-day seminar more than 50 participants representing 39 industrial and university laboratories and Government standards laboratories obtained firsthand information on statistical experiment designs especially tailored to the needs of calibration laboratories for making economical intercomparisons among sets of standards. Presentations by NBS statisticians were complemented by reports from Bureau calibration laboratories that are implementing the new computer-aided methods for data analysis, preparation of calibration reports, and surveillance of the measurement process.

Calibration of Thermocouples and Optical Pyrometers.—Scientists and technicians from both Government and industrial standards laboratories attended a 5-day seminar on techniques for the calibration of thermocouples and optical pyrometers led by members of the NBS staff.

Precision Calorimetry.—A four-day seminar was held covering the field of precision calorimetry. Lectures on apparatus design and measurement techniques for use with cryogenic to very high temperatures were supplemented by laboratory demonstrations.

Commission on Illumination.—The International Commission on Illumination (CIE) held its 16th quadrennial Session in Washington, D.C. June 19–28, 1967. The Commission visited NBS laboratories and examined its current program in photometry and radiometry.

RF Voltage Measurement Seminar.—This three-day seminar was offered twice in June at the NBS Radio Standards Laboratory in Boulder, Colo. It covered primary voltage standards, calibration equipment and techniques, methods of extending voltage ranges, thermal noise related to voltage measurements, introduction to commercial instruments, and peak pulse standards and calibrations.

Phase Shift Measurement Seminar.—A three-day seminar on phase shift measurement was offered. Subjects included basic concepts and equations, low frequency measurements, a 30 MHz modulated subcarrier system, broadband measurements, UHF and microwave differential phase shifters, and techniques applicable to UHF, microwaves, swept frequencies, and time delay.

THE NATIONAL STANDARD REFERENCE DATA SYSTEM

The National Standard Reference Data System began in 1963 when the Federal Council for Science and Technology directed NBS to assume responsibility for all Government-wide standard reference data compilation activities. NBS was requested to (1) coordinate existing data compilation and evaluation activities throughout all Government agencies and ensure their compatibility; (2) establish standards of quality for products to be designated as Standard Reference Data; (3) establish standards of methodology including machine processing; and (4) operate a National Standard Reference Data System.

NSRDS is concerned, under these instructions, with the production and dissemination of compilations of critically evaluated data. A primary emphasis of the system is to maximize the utilization of numerical information already reported in the scientific literature. The program includes collection and evaluation of data from the literature, preparation of critical reviews dealing with the state of quantitative knowledge in a particular technical field, and computation of useful functions derived from Standard Reference Data or used in the interpretation of quantitative experiments.

Within the Federal agencies, broad interest in planning and coordination of scientific information problems is focused in the Committee on Scientific and Technical Information (COSATI), which sponsors a number of Panels and Task Groups on special topics. The newest COSATI Panel, on Information Analysis Centers, has many common interests with NSRDS. Three members of the NBS Office of Standard Reference Data have accepted assignments on this COSATI Panel.

INTERNATIONAL DATA ACTIVITIES

One of the primary functions of the NBS Office of Standard Reference Data (OSRD) is to become affiliated with international groups having special interest in the data process. In addition, since NBS is charged with coordinating all Federal data activities, it is often called upon to represent the United States in international groups. Fulfilling such responsibility requires that OSRD be familiar with data activities in other countries and with all such work being conducted on an international basis.

International interest in data compilation is increasing markedly. Several years of planning have led to formal recognition of an international structure to channel this interest effectively. Under the stimulus of the Foreign Secretary of the National Academy of Sciences, the

International Council of Scientific Unions established a "Committee on Data for Science and Technology." This committee (called CODATA) has a directive to promote international cooperation, to serve as a channel of communication among data projects in countries throughout the world, to encourage more scientists to undertake projects of this type, and to make recommendations about needs and priorities to persons responsible for funding such projects in the various countries.

Membership in CODATA consists of national representatives from the United States, United Kingdom, USSR, France, Germany, and Japan, plus representatives of those international scientific unions that wish to participate. Ten unions have chosen to do so.

The international scientific unions as non-governmental organizations are autonomous in defining their relationship to governmental programs. Preliminary informal discussions have been held regarding the desirability and feasibility of conducting an international standard reference data program under the auspices of an intergovernmental organization, such as the Office of Economic Cooperation and Development, one of the United Nations specialized agencies, or a new agency created for the purpose.

This same international interest has led to domestic data compilation programs in several other countries. In the United Kingdom, government responsibility for developing a program has been assigned to the Office of Scientific and Technical Information within the Department of Education and Science. This office has conducted a survey of existing activities and capabilities within the UK and is now supporting a number of projects after checking with NBS to determine that there was no conflict in plans.

In Germany, editors of the Landolt-Bornstein data compilations and the managements of the government-supported Gmelin Institute and the Beilstein Institute have expressed considerable interest in the National Standard Reference Data System and have shown a desire to cooperate with the U.S. program. In addition, discussions have been held with representatives of the Deutsche Forschungsgemeinschaft and the Institut für Dokumentation.

The USSR State System of Standard Reference Data (GSSSD) is a responsibility of the State Committee on Standards. Officials of the GSSSD have expressed a desire to establish close personal relationships between the United States program and their own. These relations would include machinery to communicate directly, exchange of documents and visits, and work to obtain common solutions to problems of classification, storage, indexing, and related matters. GSSSD officials have indicated that they consider the U.S. program to be the "father" of theirs, and that U.S. reports have influenced substantially their concepts of the proper nature of a standard reference data system.

Although the Soviet program has been in existence only about one year, they now have approximately 120 persons in the central office (as compared to 14 in the NBS office). The technical scope is broader, including less well-defined properties of complex materials, customarily called "engineering properties," which are not included in NSRDS. In addition, the Soviet program plans to exercise more direct control over experimental measurements than is envisioned in the U.S. program.

Approximately 100 titles are now in preparation under the auspices of the GSSSD. These works are concerned with data evaluation, critical reviews, state-of-the-art reviews, and measurements methodology. The technical areas receiving most emphasis are thermodynamics and transport properties and chemical kinetics. Most of the 100 works in preparation are to appear by 1970.

One of the major projects is a multivolume work containing a complete review of the quantitative data on the kinetics of chemical reactions; this is to appear in three parts concerned with gas phase reactions, liquid phase reactions, and solid phase reactions. The International Steam Tables Project and the International Union of Pure and Applied Chemistry Project on Industrially Important Gases have stimulated major projects for experimental measurement and data evaluation. A volume equivalent to NBS Circular 500 is in preparation, and is to be revised regularly. (This work is concerned primarily with standard free energies of formation.) Another major effort within the Soviet Union is concerned with refining the values of the fundamental physical constants. Plans have been made within GSSSD to establish a national nuclear data center in the near future, and a geophysical data center is being considered.

DATA PROJECT ACTIVITY

In spite of funding restrictions and resultant program curtailment, the past year has seen a significant volume of publication from NSRDS. Four data compilations in the NSRDS–NBS series were issued, and six other products were completed. Twelve additional manuscripts were written and submitted for publication during the year. As a result of this increased output, the NBS Office of Standard Reference Data is better able to explore with the scientific community the general needs for reliable reference data and to evaluate the design of individual compilation projects.

Nuclear Data

In the national program for data compilation, the primary role of OSRD has been to maintain contact with nuclear data compilation and evaluation activities and to provide assistance where requested.

Direct administration of data projects is provided by the Atomic Energy Commission.

The effort in nuclear data activities has undergone a major change in the past year as a result of (1) the AEC decision to establish a National Neutron Data Center at Brookhaven National Laboratory combining the work of the Sigma Center (Neutron Cross Section Compilation Center) and the Neutron Cross Section Evaluation Center, (2) the work of the latter Center in coordinating the development of an Evaluated Nuclear Data File of a complete set of evaluated neutron cross sections for a large number of nuclides important in reactor applications. Responsible for the success of this ENDF work is the fact that a large number of scientists, already engaged in the compilation and evaluation of nuclear cross sections, contributed to this work. This activity has taken three main directions: (1) The actual evaluation work itself, which consists both of new evaluations based on the latest data and also of old evaluations recast in a new format. (2) Preparation of machine programs for automatically handling cross section data. (3) Documentation of the evaluation.

Atomic and Molecular Data

The Office of Standard Reference Data continued its support of specific data compilation projects on the following subjects:

Atomic energy levels
Atomic transition probabilities
Atomic and molecular cross sections for electron and heavy particle collision processes
X-ray attenuation coefficients
Atomic x-ray wavelengths
Spectra of selected diatomic molecules
Infrared, mass, and microwave spectral data
Molecular vibration frequencies
Ionization and appearance potentials

Output from the Atomic and Molecular Properties program included the following titles:

1. The Band Spectrum of Carbon Monoxide, by Paul Krupenie
2. Tables of Molecular Vibrational Frequencies, by T. Shimanouchi
3. Bibliography of Low Energy Electron Collision Cross Section Data, by L. J. Kieffer
4. Bibliography of Flame Spectroscopy, by Radu Mavrodineanu
5. X-ray Wavelengths and Reevaluation of X-Ray Atomic Energy Levels, by J. A. Bearden, *Rev. Mod. Phys.*, Vol. **39,** No. 1, 78–124, January 1967.

In addition, NBS, the Atomic Energy Commission, and the Advanced Research Projects Agency of the Department of Defense collaborated in supported a series of critical review monographs on special topics in theoretical chemistry and collision processes.

In addition to a formal international approach, informal cooperative efforts on topics associated with the atomic and molecular area are developing at the working level. For example, U.S. compilers of data on mass spectrometry are arranging to provide information and data to the UK Mass Spectrometry Data Centre at Aldermaston, as part of a joint program. Other NSRDS compilation projects considered for activation have been coordinated with similar work already going on in other countries—Germany, France, Japan, etc.

The Advisory Panel on Atomic and Molecular Properties, of which Professor E. U. Condon of the University of Colorado is Chairman, met in Washington, D.C., in May 1967. The Panel reviewed current activities, recommended changes, and suggested priority ratings for program expansion.

Solid State Data

The NSRDS program in this area includes compilation projects on crystal structure, properties of superconductors and properties of metals and alloys. The program on crystal structure focuses on a revision of Donnay's "Crystal Data." In addition to revision of the tables, the project is developing a completely computerized system for deriving structure and recording data from the basic crystal parameters, and for computer-controlled text composition. This will permit automatic updating, revision and correction of the tables, as well as searching.

An NBS Technical Note on "Superconducting Materials and Some of Their Properties," by B. W. Roberts, was published during the year.

Thermodynamics and Transport Data

NSRDS is supporting 16 programs on thermodynamics and transport properties with the following subject-content:

Thermodynamic data on organic compounds
Chemical thermodynamic data on inorganic compounds
Thermochemical data on organic compounds
Analysis of low temperature heat data
Thermal properties of gases
Thermodynamic properties of ammonia
Thermal behavior of carbonates
Electrochemical and surface properties of fused salts
Vapor liquid equilibrium data

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Vapor liquid equilibrium data at high pressure
Phase relation data for binary systems of oxides
Thermodynamic data of inorganic phases at high temperature
High pressure data center
Diffusion in solids
Viscosity and thermal conductivity of mixtures in the gaseous and liquid state
Thermal conductivity of selected substances

In addition, a systematic review of phase diagrams for binary alloys is in progress under the technical direction of the Office of Standard Reference Data.

Output from the Thermodynamics and Transport Properties program included the following titles:

High Temperature Properties and Decomposition of Inorganic Salts, Part I, Sulfate, by K. H. Stern and E. L. Weise

Thermal Conductivity of Selected Materials, by R. W. Powell, C. Y. Ho, P. E. Liley

Thermal Conductivity of Selected Materials, Part 2, by C. Y. Ho, R. W. Powell, and P. E. Liley.

Reports on the electrical conductance, density and viscosity of molten salts, the phase behavior of the methane -*n* pentane system and of *n* pentane alone, the thermodynamic properties of the alcohols, and selected values of thermochemical properties are nearing completion.

Chemical Kinetics Data

The NSRDS approach to the area of Chemical Kinetics stresses the preparation of critical review monographs to define the status of available quantitative information on narrow topics. In addition, kinetics data centers are set up to:

(a) provide authors of monographs with bibliographic services and assistance,
(b) maintain coverage of the scientific literature on a current basis,
(c) store and classify the data and bibliographic content of critical review monographs,
(d) provide information to the scientific public on the basis of items (b) and (c).

Two manuscripts, "Tables of Bimolecular Gas-Phase Reactions," by A. F. Trotman-Dickenson, and "Catalytic Hydrogenation of Ethylene," by J. Horiuti, have been submitted for publication.

Two data centers have been established, the NBS Chemical Kinetics Information Center acting in a general capacity, and the University of Notre Dame Radiation Chemistry Data Center. These centers are at present performing the first two services listed above, and are providing some limited information services to the public as well.

In addition, the NSRDS kinetics program now includes a limited number of projects for evaluation and tabulation of reaction rate data of special interest, supplementary to the critical review activities.

Colloid and Surface Data

Two new compilation projects were started in 1967. One, the critical evaluation of data on the surface tensions of substances which are liquids in the vicinity of room temperature, complements an existing program on the surface tensions of molten salts. The other new project is a critical review of data pertinent to phase transformation kinetics including such factors as coefficients of evaporation and condensation, critical supersaturations and specific interfacial energies. Among the older programs, one on the critical micelle concentrations of association colloids and another on the light scattering of pure liquids and binary mixtures are nearing completion.

There are three other active projects of data compilation and evaluation in this area. They are sponsored by the NAS/NRC Committee on Colloid and Surface Chemistry, and concern heats of immersion, the surface tension of solutions of association colloids and the properties of monolayers.

INFORMATION SYSTEMS DESIGN AND RESEARCH

A survey of the physical tables literature is being made, and a bibliographic list, author index and classified subject index of tables has been prepared in the area of solid state physics.

To promote international cooperation and compatibility of computer programs and formats used by data centers for physical properties of materials, the Committee on Data for Science and Technology (CODATA) of the International Council of Scientific Unions has established a "Task Group on Computer Use" with which NBS cooperates.

The organizing meeting of the Group laid plans for a status report on automation in data centers and for an inventory of appropriate computer programs, to be followed later by recommendations for uniform codes and formats, exchange of computer programs, and promotion of computer use in data taking and evaluation.

INFORMATION SERVICES

Information services activities this past year were restricted primarily to assisting and supporting data centers. Emphasis was placed on file and publication mechanization procedures of general applicability, on developing increased cooperation among data centers, and on determining the needs of the scientific community.

Machine-Readable Scientific Text.—A "General Purpose Scientific Document Image Code" has been developed as the central component of a system for mechanizing the processing and exchange of scientific information in machine readable form. Such a system is needed by the data and information centers supported by the Office of Standard Reference Data. In this system a scientific typescript, with all its traditional complex symbolism and highly structured page format, may be transferred to digital machine form with virtually no limitations on the notation that may be employed.

An attempt was made in the design of the system to assure broad applicability by emphasizing (a) exchange of information via telecommunication devices compatible with the American Standard Code for Information Interchange, (b) design of hardware to permit use of the proven skills of ordinary scientific typists in the record capture process, (c) exploitation of the capabilities of commercially available extended character high-speed line printers for direct computer output, and (d) publication using this type of machine record as the "typescript" input to computerized typesetting programs.

This system was developed in the NBS Physical Chemistry Division, and is being tested on records produced by the Chemical Kinetics Information Center and the Chemical Thermodynamics Data Group located there. To date two prototype "taxywriters" (type-augmented x-y recording typewriters) have been built. Computer programs for the input, editing and retrieval of records have been written and tested on a pilot plant scale. Tests indicate that the System will be readily adaptable to other data collection operations.

Discussion Forum, Data and Information Center Operators.—A meeting of all data and information center operators associated with OSRD was held April 6–7, 1967 at NBS. Representatives of 18 data and information centers within NBS and 10 centers outside the Bureau participated in the forum. The major objectives of the meeting were: (a) to examine and develop machinery for communication exchanges and work sharing; (b) to explore means for establishing compatibility among operational procedures of the centers; (c) to explore and help formulate standards of quality; and (d) to define relationships between and among the Office of Standard Reference

Data and associated centers and to develop machinery for more effective aid to centers.

Survey on Data Needs.—The Office of Standard Reference Data in cooperation with *Industrial Research* magazine conducted a survey in the magazine's May 1967 issue to determine:

(1) Data and information needs of scientists and engineers within the industrial research community.
(2) How such needs are now met.
(3) Patterns of use of data, information, and reference sources.
(4) Problems in finding required data and information.

Results of the survey show:

(1) That of about 600 scientists and engineers responding, 75 percent experience problems in locating or obtaining materials properties data.
(2) During a typical week, 55 percent of the respondents must look up properties data from 1–5 times. Among others, the task is more demanding—occurring 6–10 times for 22 percent and more than 10 times for 19 percent.
(3) Generally it takes less than an hour for the majority to locate the necessary information. However, 24 percent spend from 1 to 8 hours; and 8 percent normally search for days or weeks.

Among other items of interest the survey revealed was:

(1) The printed book is the most frequently used and preferred form of data in use by the respondents.
(2) Seventy-two percent of the respondents require and use bibliographies.

The survey showed that 82 percent of the respondents were engaged in research and development; 17 percent in manufacturing and processing. The disciplines represented were: 37 percent in chemistry; 32 percent in engineering; 12 percent in physics; 8 percent in the life sciences; the rest divided among miscellaneous groupings.

INSTITUTE FOR MATERIALS RESEARCH

The Institute for Materials Research is one of the nation's principal materials science laboratories. Work falls into the following broad areas:

1. Preparation and Characterization of Materials
2. Data on the Properties of Materials
3. Technical Assistance to Others.

The full-time staff of about 600 employees includes a professional staff of 400 with 160 Ph.D.'s in science and engineering. In addition, there is a part-time staff of about 60 scientific consultants, Research Associates, and Fellows.

The work of IMR facilitates the application of materials science to the solution of national problems by conducting research on materials and by supplying consulting and various other services. IMR provides the national science capability to support the NBS leadership role in the national measurement system. About 40 percent of IMR's work is for other Government agencies.

PREPARATION AND CHARACTERIZATION OF MATERIALS

This area includes such activities as the synthesis of new materials, purification of materials, crystal growth, and the analysis of materials with respect to chemical composition and structure. Outputs of these activities are sample materials to be used for specific research purposes, and the development of new techniques and procedures for preparing or characterizing materials. Another output is a class of materials called Standard Reference Materials. These are prepared and sold by IMR and are used mainly by industry for the calibration of equipment.

PREPARATION

Synthesis

Ion-Exchange Resins Under Study.—An effort was directed toward the preparation of ion-exchange materials tailored to specific separation problems. Initial efforts have demonstrated the feasibility of controlled surface sulfonation such that cation exchange capability is restricted to a depth of 10 nanometers. This work is part of a general program which seeks to control chemical reactions which cause ion-exchange capacity to develop, and which will point the way to the

fabrication of ion-exchange materials with predictable and unusual properties.

New Silicon Compounds.—The preparation of a family of silicon compounds and a novel approach to their identification have been achieved. The compounds are mixed halodisilanes—molecules containing directly connected silicon atoms bonded to varying numbers of chlorine and fluorine atoms. Identification of individual compounds and unequivocal structure determination—a major problem in the complex mixtures obtained in this work—was accomplished by a nuclear magnetic double resonance method that makes use of small amounts of a particular silicon isotope. The new materials, which are inorganic analogues of the fluorocarbons, are under study as part of a program dealing with chemistry of metal-metal bonds.

New Inorganic Free Radicals.—The decomposition and formation of inorganic molecules under the influence of light are being studied with the ultimate goals of developing photochemical synthetic procedures and of better understanding of radiation damage effects. Recent experiments show that two new inorganic free radicals, PCl_2 and PCl_4, can be produced by irradiating phosphorous trichloride at low temperatures. Present results indicate that detailed studies of the new radicals may also yield important information about the effects of impurities on molecular motions in polycrystalline solids. By irradiation of organometal halides with ultraviolet light, evidence has been obtained for the formation of the new inorganic free radical, SiCl. It has been demonstrated by electron paramagnetic resonance techniques that the methylchloro derivatives of silicon and tin produce radicals by cleavage of the metal-carbon bond at liquid nitrogen temperatures. These are of interest as potential reactive intermediates. Presently several interesting systems are being studied including catenated halides (Si_2Cl_3 and Ge_2Cl_3), mixed hydrides ($HSiCl_3$) and other halides such as PCl_3.

Procedure for Homogeneous Anionic Polymerization.—A detailed "state of the art" review paper on methods of preparation of vinyl-type polymers (polyisoprene, polystyrene, and polybutadiene) using organic-metallic catalysts has been published (NBS Journal of Research, **70A** Sept.–Oct. 1966). The review discusses the conditions required to be maintained if precise control over molecular weight and narrow molecular weight distribution are to be achieved. These include rigorous exclusions of substances capable of terminating the polymerization and uniformity of reaction conditions such as temperature and reactant concentration.

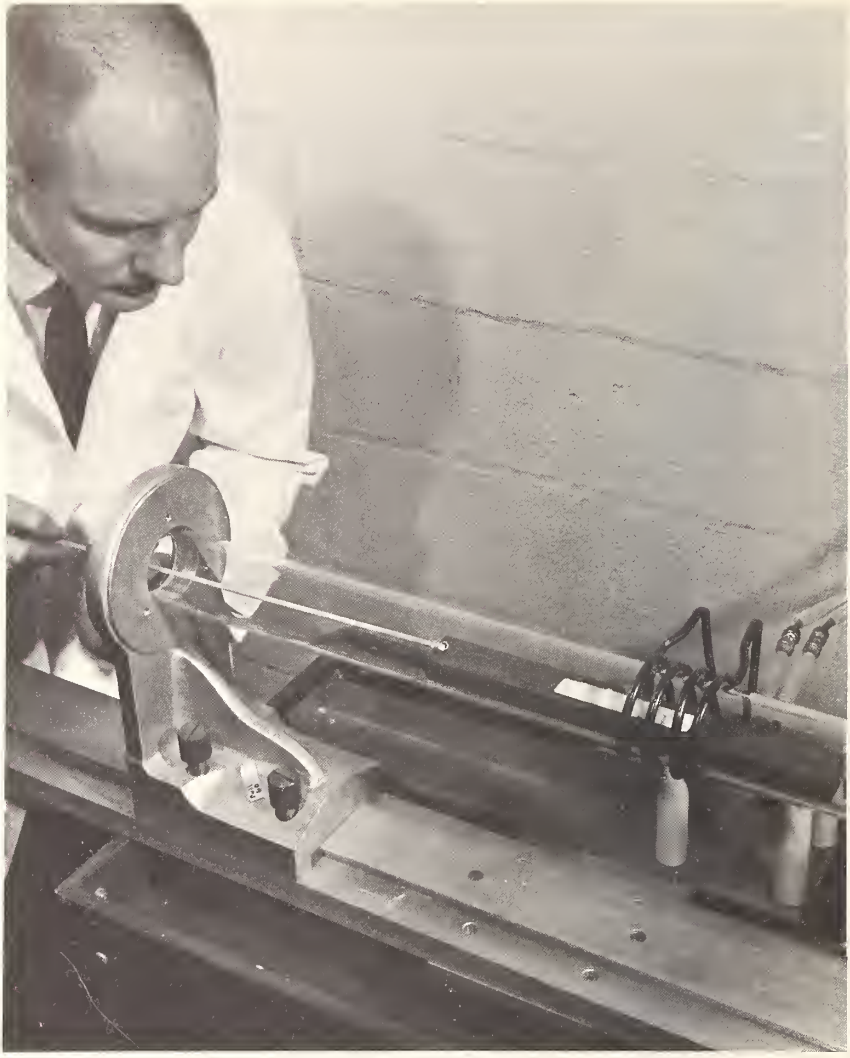
Crystal Growth

Melt Growth of Crystals.—Large single crystals of the tungstates and molybdates of calcium and lead have been grown by Czochralski's pulling method. The perfection of these crystals has been investigated using etching techniques; typical dislocation densities are in the range of $10^3/cm^2$. The crystals are being used as research specimens for the measurement of optical, mechanical and electrical properties. The possibility of using them for laser applications is being investigated.

Mother-Liquor Inclusions in Crystals.—Inclusions of mother liquor in solution-grown crystals adversely affect the use of the crystals in science and industry. Recent observations, particularly in crystals of sodium chlorate and ammonium dihydrogen phosphate, suggest that inclusions in these systems are due to a rise in super-saturation of the parent solution. Crystal faces may then develop "hopper" growth or other irregularities. When supersaturation is subsequently reduced, overgrowth of irregularities can take place, leaving inclusions behind. The resulting macroscopic defects do not heal readily.

Theory of Polymer Crystallization.—A general theory of crystallization in multicomponent systems has been developed that is applicable to alloys, short-chain systems such as mixed paraffins, and the chain-folding problem in polymers. This theory permits rate of growth calculations of a chain consisting of several components as well as calculation of the average composition of the chain at various rates of growth. The full kinetic equations for the growth of such chains have been formulated and a solution has been derived for steady-state conditions.

Thermal Convection During Crystal Growth.—The structure and properties of melt-grown crystals are known to be affected in important ways by the presence of thermal convection in the melt from which the crystal is being grown. (Thermal convection is fluid motion resulting from temperature differences). The opacity of molten metals makes the direct observation of their flow impossible. In recent work, the metal system was simulated with a transparent salt whose flow characteristics approximate those of metals. The most important finding was the observation of vertical currents, which did not remain fixed in position for any length of time but shifted erratically. In addition, a thermocouple probe technique for measuring flow direction and velocity was developed. Its measurements were checked in the transparent system against the velocities observed in the salt and found to agree. The technique was then used to establish the nature of flux patterns in liquid metal systems.



By simulating opaque metals systems with a transparent salt, NBS investigators were able to determine molten metal flow patterns and velocity. Here, a horizontal boat containing a salt in the heating element is being positioned for an experiment.

CHARACTERIZATION

Composition

Nondestructive Analysis of Proteins.—In a practical solution to a major problem of biochemical analysis, a method has been devised for determining the total elemental content of proteins. With the use of neutron activation methods, 10-milligram samples of amino acids and

proteins have been analyzed with a precision of 5 percent. Futhermore, the analysis has been accomplished without destroying or damaging the specimen. Analytical results comparing well with those obtained by tedious, destructive chemical methods have been obtained for four elements: oxygen, nitrogen, sulfur, and phosphorus. The method is of considerable promise for biomedical research, particularly where a knowledge of the elemental composition is necessary prior to biological tests.

Rapid and Accurate Electron Probe Analyses.—The electron probe microanalyzer, a recent development, has proven to be a powerful tool for the nondestructive analysis of solid surfaces. Surfaces are scanned with a very narrow beam of electrons and the resulting x-ray emission produces a spectral pattern characteristic of the elements present and their amounts. These patterns are complex and their analysis is time-consuming when quantitative data are required. Rapid and accurate analyses were accomplished by constructing an electronic device which clearly distinguishes the first-order x-ray lines from those of higher orders. Simplified wavelength tables were also prepared, and with their aid the elements present in the sample can quickly and easily be identified from the x-ray lines observed.

Determination of Oxygen in Steel.—The great sensitivity of the mechanical properties of structural steel to the amount of dissolved or interstitial oxygen has made the routine determination of oxygen of considerable importance in steel fabrication. A new biaxial rotating assembly for use with neutron activation techniques for oxygen analysis has brought about a tenfold increase in analytical precision. In the use of the new assembly, the unknown and standard samples are injected pneumatically into the neutron field where they rotate about two perpendicularly oriented axes in such a way that both experience an identical neutron environment.

Increased Precision of Lead Isotope Determinations.—A new technique for the mass spectrometric determination of lead isotope composition has been developed. This technique, which involves the use of a triple-filament solid-sample source, increases the precision of lead isotope measurements by a factor of 5 as compared to previous methods. The increased precision will be of great help to earth scientists involved in the study of fundamental chemical characteristics of the earth as well as in age determination studies of rocks, minerals, and meteorites. The technique is presently being used for the determination of the absolute lead isotope composition of a number of standard reference materials, and in a study of the possible use of lead isotopes as a marker for distinguishing sources of archaeological artifacts.

Trace Quantities of Carbon in Sodium Metal.—Development of breeder nuclear reactors requires analysis of liquid sodium (a coolant) for trace elements such as carbon. A variety of analytical techniques have been used for carbon analysis with little success. This has now been done with the use of photonuclear activation analysis. This technique permits carbon analysis in sodium metal to a level of 10 to 100 parts per million with a precision of 5 percent relative standard deviation of a single determination. Where other analytical methods have required several hours per sample, this technique requires approximately 30 minutes per sample for analysis.

Procedure Enhances Accuracy of Spectrophotometric Analysis.—Spectral absorption in the visible or ultraviolet regions of the spectrum forms the basis for some of the most useful methods of chemical analysis. Unfortunately, the inherent sensitivity of the spectrophotometric technique is governed by cross sections of the light-absorbing molecules which never exceed their physical dimensions. "Amplification" procedures have recently been explored as a means of overcoming these sensitivity barriers. In the determination of arsenic in high-purity selenium, for example, the arsenic can be separated from the matrix and determined spectrophotometrically by the heteropoly molybdenum-blue method. The detection limit is about 5 ppm. However, an increase in sensitivity can be obtained by converting the arsenic into an arsenomolybdate complex which is subsequently decomposed and molybdenum determined spectrophotometrically as the yellow chelate with quercetin. Inasmuch as 12 atoms of molybdenum combine with each atom of arsenic, a twelvefold "amplification" is achieved. Accordingly, the sensitivity limit is found to have been lowered from 5 ppm to about 0.5 ppm by the new procedure.

High-Accuracy Titration for Small Samples.—Modern analytical chemistry is continually being urged to provide methods capable of yielding accurate results with ever smaller samples, and frequently it is essential that the analysis be made without contaminating the sample and destroying its subsequent usefulness. An improved method of null-point potentiometry has been refined to the point where it is now possible to determine one ten-millionth of a gram of silver in two drops of solution with a accuracy of about 5 perecent. To achieve this, the small sample is brought into electrical contact through a porous glass septum with a similar solution containing no silver. A carefully measured amount of electricity is then made to generate silver in this reference solution until indicating electrodes show that the concentrations are equal in the two solutions. The entire analysis can be carried out without contaminating or altering the sample in any way. Automation of the process is possible, and computer analysis of the results provides a considerable saving of time.

New Method for Determining Trace Elements by Mass Spectrometry.—A new method has been developed for the determination of trace elements in the parts per million range. The method combines the principle of isotope dilution with electrolytic separation and determination by the spark source mass spectrometer. The new method yields high sensitivity and permits several elements to be determined simultaneously. Furthermore, the use of the isotope dilution technique makes it unnecessary to assure a quantitative yield or even to determine the yield percentage. This method was used in an analysis of zinc metal to be issued as a standard reference material. Lead up to the 10 ppm level was determined with a precision of about 4 percent, whereas cadmium and thorium at the 1 percent and 0.1 percent levels were determined with a precision of about 10 percent.

High Precision Flame Emission Spectrophotometry.—A new technique of differential flame emission spectrophotometry was developed whereby a precision of one part in a thousand was obtained over a concentration range from a few ppm to several percent. This is a tenfold increase in precision over the previous procedure. The new approach has made it possible to achieve the needed accuracy in the determination of the lithium content of glass beads for neutron flux measurement. Although only a small amount of valuable sample is required, the error of the analysis is below the set limits of 0.2 percent. To achieve this increase in precision a phase shifter and attenuator were built for the a–c synchronous detector. This modification in the electric circuit permitted the setting of any desired concentration at zero percent transmission and then a finite concentration above this value was expanded to give full-scale deflection.

Improved Sensitivity of Sulfur Analysis.—Emission spectrochemical procedures are commonly used to evaluate the relative purity of sulfur samples, yet the high volatility of sulfur in the arc results in poor sensitivity of detection for the impurity elements. A new way has been found to concentrate these elements twentyfold, thus enhancing significantly the sensitivity of detection. At the same time, the troublesome volatility of the sulfur is avoided by complete oxidation of the sample, whereupon the metallic oxides are then easily determined in the conventional way. By this method, 11 elements present in a sulfur sample at less than one part per million have been detected easily.

Glass Electrode in Heavy Water.—The behavior of the glass electrode in heavy water has been determined. The electrode was found to be nearly as suitable for measurements of acidity in heavy water as in ordinary water. The way is paved, therefore, for establishment of a practical scale of acidity or pD in heavy water which is a major constituent of many nuclear reactors.

The response of glass electrodes to deuterium ions in heavy water is determined by direct comparison with the deuterium gas electrode. A knowledge of the glass electrode errors in heavy water is essential to accurate pD measurements with the pH meter.

Structure

Kossel Microdiffraction Generator.—A Kossel x-ray generator has been developed to permit diffraction studies of local areas of crystalline materials typically 2 microns in size. The samples can be oriented in space with respect to the incident electron beam about any axis of tilt in order to obtain the desired diffraction conditions. A microtensile stage was developed to permit the application of stress to the specimen while under study. Local measurements of the lattice constant can be made with great precision by this technique.

Photographic Scanner for Quantitative Microscopy.—An automatic optical scanner has been developed for digitalizing pictorial information present in photographic prints up to 10 x 10-in size. The continuous intensity data is represented as one of 16 different levels on a grey scale and a spatial resolution of ¼ mm can be obtained. The scanner has been applied to studies of grain size and precipitate size in several metallurgical alloys of commercial interest. Greatly increased precision and lack of reader bias have been demonstrated over previous manual methods of analysis.

Examination of Meteorites.—In a cooperative study with NASA Goddard Space Flight Center, IMR metallography facilities are being used to examine metallic phases in meteorites. For 150 years, such phases were examined in ordinary white light illumination. Now a color polarizing technique is being used to complement, and in some cases improve upon, earlier observations. Approximately 6 percent of the world's known iron meteorites have been photographed in this program.

Field-Ion Microscopy of Ruthenium.—Field-ion microscopy, a way of studying the arrangement of atoms on the surface of a material, has been used to study the surface structure of ruthenium, a hexagonal close packed metal. It has been possible to extend measurements to relatively high temperatures (78 °K). The structure of dislocations as they intersect the surface has been studied, and theoretical predictions as to the nature of this structure have been confirmed.

Polymer Characterization.—The properties of different polymers in solution are being studied by various methods such as osmometry, light-scattering, viscometry, and ultra-centrifugation. Molecular weight data have been obtained on such polymers as polystyrene, polyethylene and polyisocyanate. Several coordination polymers such as those containing Be (II) and Cr (III) linked to *bis*(8-hydroxy-5-quinolyl) methane in the backbone have been investigated with respect to their thermal stability in vacuum using thermogravimetric analysis.

Rodlike Polymer Molecules.—Stiff rodlike polymer molecules of poly(*n*-butyl) isocyanete have been synthesized and characterized in dilute benzene solutions. Dielectric measurements over a frequency range of 10^{-1} to 2×10^{6} Hz have related the relaxation time to the molecular weight of the macromolecule. This study indicates that the net dipole moment is parallel to the major axis of the rodlike molecule and the observed dielectric relaxation time is related to the end-over-end rotation of the molecule around its minor axis. The high degree of asymmetry of these polymers simulates that found in certain biologically important systems such as proteins and polypeptides.

Single-Axis Two-Crystal X-Ray Instrument.—A two-crystal x-ray diffraction instrument has been designed, constructed and operated in which the diffraction angle can be measured with a precision of about one-half microradian. The instrument is being used to measure microstrains in single crystals of very high perfection.

Characterization of Ceramic Materials.—The microstructure of polycrystalline ceramic materials was studied by transmission of elec-

tron microscopy and defects such as dislocations, impurity precipitates, second phase materials, and voids were detected and identified. Commercially prepared pure oxide ceramics, alumina, and magnesia, and a metal-ceramic composite were sectioned and then thinned to a thickness of a few hundred nanometers by sputtering with argon ions. The boundaries between crystallites or grains were preserved by the thinning method and could be imaged as wedge fringes.

Properties and Structure of B_2O_3 Glass.—Boron trioxide glass, one of the few pure oxides which can conveniently be obtained in the glassy state, is under exhaustive study. A problem in making physical measurements with B_2O_3 has been its water content. A standard drying procedure, which not only minimizes but also standardizes the water content of the samples, has been developed. Since the chemical characterization of a glass former is based on its viscosity, a very accurate and extensive set of measurements (20 poises at 1400 °C to 10^{10} poises at 320 °C) has been made. The density, with its anomalous expansion coefficient, has been determined. In addition, the shear and longitudinal ultrasonic velocities and absorption were determined through the glass transition temperature and up to 1450 °C. From these data a thermodynamic model has been proposed for vitreous B_2O_3, where both the liquidlike and glasslike properties are considered as well as phenomena associated with the kinetics of flow.

Crystal Structure Determinations.—Knowledge of atomic configurations in materials is required to understand many physico-chemical phenomena. Such diverse properties as hardness and infrared and optical spectra depend on intimate atomic structure. Recent x-ray diffraction studies have produced the first published, complete structure analysis for a heteropoly compound, sodium hexamolybdochromate, in which all cations and water molecules are unequivocally located.

STANDARD REFERENCE MATERIALS

Standard Reference Materials are well-characterized materials that can be used to calibrate a measurement system, or to produce scientific data which can be readily referred to a common base. They assist realization of major national goals dependent on technology and commerce by assuring the uniform and compatible measurements on which quality control and performance characteristics are based.

Prepared and certified by NBS, Standard Reference Materials are sold to industrial and scientific organizations of this country and throughout the world. They transfer urgently needed NBS calibration technology for use in creating, manufacturing, and distributing a wide variety of products vital to the economic life of the nation. They are also playing an ever more important role in the nation's sociological (e.g., air pollution control) and defense needs.

During the year 26 new items were prepared, certified, and distributed. In addition, 36 renewals of standards which had gone out of stock were issued. More than 600 Standard Reference Materials were available, and sales amounted to 69,704 units during the year.

There is a continuous and pressing demand for new Standard Reference Materials which exceeds the resources available for their preparation. A continuous process of judgment is necessary in deciding which new materials should be made to fulfill the most vital needs of the nation's science and technology.

Beryllium-Copper Alloys.—New beryllium-copper standards were developed in cooperation with representatives of the nation's electrical, electronics, and aerospace industries. The standards meet critical needs for analytical reference standards over the range of chemical compositions of the alloys used in specialized electronic equipment and in components of microminiaturized circuitry and devices.

Light-Sensitive Plastic Chips.—Stability of color and transparency are important in plastics and textiles. These materials and their coloring agents are under continual testing to improve stability and to control quality for uses such as automobile upholstery, plastic building materials, and decorative materials. Natural light and weathering conditions are not easily nor completely reproducible and are slow processes. NBS has provided materials calibrated against a standard radiation source by a prescribed procedure. These may be used as reference materials in the control, comparison, and standardization of artificial fading and weathering apparatus. They have the further advantage of producing controlled fading at a much accelerated rate.

Carbon Dioxide in Nitrogen.—Carbon dioxide-in-nitrogen standards were developed to calibrate monitoring instruments which determine the amount of CO_2 pollution in the atmosphere. For simultaneous data collection and monitoring of carbon dioxide pollution levels at widely separated geographic locations, samples must be taken continuously or at intervals over a long period of time and measurements of concentration must be closely tied to a standard. Very precise measurements may be made by determining the deviation from a base line which will be established by the standards developed.

Oxygen in Metals.—Oxygen reacts with constituents of alloys to form solid, brittle inclusions which cannot be tolerated in metals for such critical applications as aircraft landing gear, pressure vessels for nuclear reactors, components of space vehicles, drill pipe for deep oil wells, or in piping for high-pressure lines. Five new standard reference materials were prepared and certified for oxygen content. Three of

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these are steel standards and the others are titanium-base alloy standards. They provide materials of known oxygen content and homogeneity, and are intended primarily for calibrating vacuum fusion or inert gas fusion equipment used in correlating the oxygen contents of metal with fabricating and performance characteristics.

Plutonium Metal.—To provide a continued supply of a reference standard for the chemical assay of plutonium, a renewal of plutonium metal was issued. Accurate assay of this element is important to the rapidly expanding nuclear industry for inventory control of fissionable material and in many of the nation's research activities related to nuclear energy. This material was prepared and analyzed by the Los Alamos Scientific Laboratory of the University of California, Los Alamos, N. Mex., in collaboration with NBS. This high-purity plutonium metal assays at 99.99 ± 0.08 percent.

Zinc Freezing-Point Standard.—A zinc freezing-point standard reference material has been prepared that meets all of the requirements of a fixed point on the International Practical Temperature Scale. The standard has a purity of 99.9999 percent. The zinc point is eventually expected to replace the sulfur point on the IPTS. Such an action will be an important step in the maintenance of the temperature scale, and will require the international availability of well-characterized, high-purity zinc standards.

Standard Metallo-Organic Compounds.—Renewals of six metallo-organic standards were issued to replace stock exhausted by sustained heavy demand. A series of metallo-organic standards was originally developed at the request of the Division of Refining of the American Petroleum Institute. At first the principal users were in the railroad and trucking industries. Here the analysis for metals in lubricating oils was used as the basis for maintenance schedules and prediction of equipment failure. Agencies of the Department of Defense now also utilize the metallo-organics for safeguarding equipment and for minimizing maintenance and repair costs. Newer uses include monitoring the presence of catalyst metals and catalyst poisons appearing in process streams of various chemical industry process plants.

Rubber Standards.—Both new and renewal standards of butyl rubber were prepared and certified. These standards are vital to process control of rubber used in the production of the more than 50 million original and replacement tires annually for the nation's automobiles.

DATA ON THE PROPERTIES OF MATERIALS

This program area includes making precise measurements of materials properties and the development of new techniques for so doing.

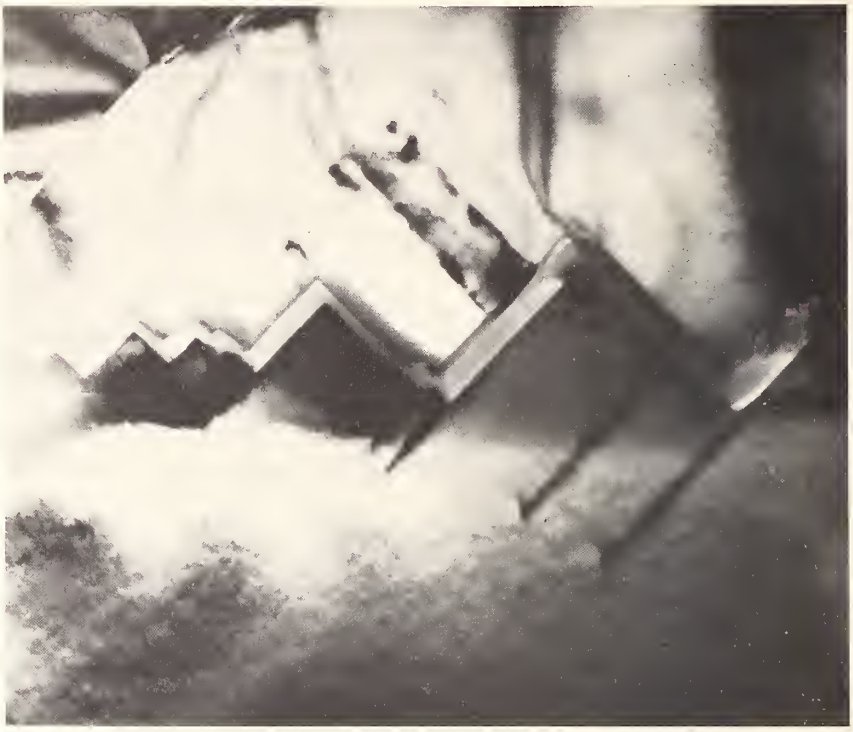
It also includes fundamental investigations of physical phenomena of importance to science and industry (corrosion, fatigue and fracture, etc.). Establishing the laws relating the physical properties of materials to their characteristics is of prime concern. Theoretical work plays a major role in this area.

Mechanical Properties and Strength of Materials

Relaxation Effects in Polymers.—A general theory which interprets the mechanical and dielectric relaxation effects found in semicrystalline polymers such as polyethylene and polychlorotrifluorethylene (PCTFE) has been developed. One relaxation process results from motions of chain folds and reorientation with translation of chains in the interior of the crystal structure. For long chains, chain twisting also occurs.

Stacking-Fault in Alloys.—The stacking-fault energy of a material is one of the basic parameters that determines its strength. The development and application of methods involving the electron microscope for the measurement of stacking-fault energies of materials are currently being extended from cubic to hexagonal silver alloys. The variation of fault energy with alloy composition has now been been established in several alloy systems, together with the effects due to the presence of trace impurities. New types of faulted defects have been observed and studied as an aid to understanding the physical behavior of these materials.

Delayed Failure of Ceramic Materials.—The strength of ceramic materials is largely determined by the mechanical perfection of their surfaces. However, the actual limit to the strength of ceramics depends more on the chemical environment to which the ceramics are exposed than on the size of the surface flaws they contain. For example, identical glass rods are three times as strong when tested in vacuum than when tested in moist air. This reduction in strength in glass is called static fatigue or delayed failure and is very similar to stress corrosion in metals, a process wherein materials are weakened by crack growth caused by the combination of applied load and corrosive environment. A new experimental technique has been used to study this phenomenon in ceramic materials. The technique uses large macroscopic size cracks that permit direct visual observation of crack motion as a function of temperature, environment, and applied load, and permits the resolution of the finer details of the fracture process. The technique has been applied successfully to soda-lime glass and is now being used to study single-crystal sapphire.



Fracture across a grain in an alumina ceramic caused by thermal shock after heating at 800 °C. The fracture surfaces are parallel to the rhombohedral planes. Fracture of this type is a frequent cause of failure in alumina. Studies are being conducted at NBS to better understand brittle fractures and thus to expand the usefulness of ceramic materials.

Low-Temperature Mechanical Properties.—The mechanical properties of selected copper alloys have been measured and an extensive literature search and critical evaluation was completed. The final report will be published as an NBS Monograph.

New Method for Studying Dental Materials.—Scientists in the NBS Dental Research Laboratory are investigating the use of ultrasonic waves to study properties of dental materials. It is well known that the elastic properties of materials can be determined from the velocities of ultrasonic waves within them, but this is the first time that the technique has been tried on dental amalgam.

Tarnishing Behavior Identifies Fatigue Fractures.—IMR researchers have observed an interesting phenomenon that provides a definite distinction between a metal fracture resulting from a single application of load and one that results from the propagation of a fatigue crack. In the course of an investigation on magnesium alloys, it was observed that fracture surfaces, which were bright when first broken,

became discolored after several months storage, but the tarnishing occurred only on the fatigue portion of the fracture. So far as can be determined, this is the first case observed in which the type of fracture has affected the chemical character of the fracture surface. Such information will be of substantial value in the examination of fractured metal parts (such as on an airplane or a large production line machine) to determine the cause of failure.

Reactivity and Corrosion

Protective Oxide Films on Iron.—Efforts are being made to determine methods of forming protective oxide films on iron in various corroding environments. A study has been completed to characterize some of these protective oxide films. By using tritium (radioactive hydrogen) as a tracer, hydrogen was found to be incorporated in those thin (2–5 nm) films which gave protection from corrosion. The hydrogen was found in highest concentrations in the γ–Fe_2O_3 outer portion of the film while lesser amounts were found in the Fe_3O_4 portion. In a second study, the effects of ultrahigh vacuum annealing of thin oxide films on iron was determined and a model to explain the results was proposed. The study found that after vacuum annealing at 400° C or above, the previously protective oxide films grew when re-exposed to oxygen at 25° C.

The Stress Corrosion of Titanium.—An investigation of the stress corrosion cracking of titanium and titanium 8Al–IV–1Mo in methanol has shown that failure will occur in the methanol vapor phase with times-to-failure being at least an order of magnitude shorter than previously reported. Those effects which significantly altered time-to-failure were system volume, metal surface conditions, and environment composition. The increasing use of titanium in the chemical industry, and in aircraft and space exploration has made such problems and their solution more important.

Protection of Steel Piles in Seawater Environments.—In a joint research effort with the Department of the Army–Coastal Engineering Research Center, over 100 carbon steel and low alloy steel piles (35 feet long, 48 lb/ft) were driven 19 feet into the Atlantic Ocean bottom off the coast of Dam Neck, Va. The results of this study, which will take about 15 years to complete, will demonstrate the best means of protecting steel pilings in seawater. Many types of protective methods are included in the investigation, consisting of coating systems (coal-tar epoxy, galvanized, aluminum and zinc flame spray, zinc-rich paints, etc.) and also cathodic protection by zinc and aluminum sacraficial anodes.

These steel piles with protective coatings were driven into the Atlantic Ocean floor to study the best means of protecting pilings in seawater.

Thermodynamics and Kinetic Data

Polystyrene Heat Capacity Values.—Over a dozen publications exist which report different heat capacity values for various samples of the polymer polystyrene. This situation has been clarified by determining values precise to better than 0.1 percent over the temperature range from 10 to 360 °K for a narrow molecular weight distribution atactic polystyrene sample. At temperatures above 100 °K these data agree within the combined limits of experimental uncertainty with most previously published values. At temperatures below about 100 °K, however, significant heat capacity differences appear, especially between the atactic and the isotactic isomers, and even between atactic samples of different molecular weight distributions and of different thermal histories.

Volume Change Accompanying Collagen Aggregation.—The natural polymeric substance collagen is a most important constituent of the human body, making up 30 percent of its protein. Industrially this polymer (the basic constituent of hide) is converted by various tanning operations to leather. In either biological or industrial application the collagen in its useful form is an aggregate of so-called tropocollagen units. By dilatometric measurement the volume of a

dispersed collagen system has been shown to increase by an extremely small amount as aggregates of tropocollagen units are permitted to form. This volume increase is attributed to a change in the ordering of the water molecules immediately surrounding non-polar surfaces of the tropocollagen units as these surfaces are superimposed. The detection of this small but real volume increase provides strong evidence that hydrophobic bonding is the driving force in the aggregation process.

Monte Carlo Studies of Polymer Chain Motion.—Existing theories of the motion of random-coil polymer chains usually neglect the mutual interference of different parts of the chain with each other (the so-called excluded volume effect). In an attempt to learn more about the effects of this interference on chain motion, a high-speed computer was used to simulate the motion of a model polymer chain. The model employed was drastically over-simplified, but contained the essential features of excluded volume interactions. The computer model may be studied either with or without excluded volume effects. Without excluded volume, its behavior has been found to be remarkably similar to the predictions of a theoretical treatment based on a picture of chain motion very different from the computer model.

Physical Adsorption.—Studies are underway to measure the adsorption isotherms necessary for the proper design of cryogenic adsorbers and to develop techniques for correlating and predicting these data. Considerable progress has been made in both of these areas. The adsorption isotherms of nitrogen, methane, hydrogen and their mixtures have been measured at 76 °K over a wide range of pressures. Techniques for correlating and predicting data of this type have also been developed and published.

Properties of Solid Hydrogen.—The dielectric constant of solid hydrogen in equilibrium with liquid has been determined, and refined measurements of the pressure-temperature coordinates of the melting line near the triple point have been made. From the latter, the density of the melting solid was calculated.

Characteristics of Slush Hydrogen.—An investigation was continued of mixtures of liquid and solid (slush) hydrogen. Particle behavior due to aging has been studied in a carefully controlled thermal environment. Flow correlations are being derived as a function of solid fraction. Instrumentation for the determination of slush density (solid fraction) has been extended to include nuclear radiation attenuation. A density reference system is also being developed for calibration of field-type instruments and transfer standards.

Kinetics of Solute-Enhanced Diffusion in Dilute fcc Alloys.—The addition of impurity atoms to a dilute alloy can appreciably change the diffusion coefficient of the matrix solvent atoms, sometimes by more than an order of magnitude. To help understand this property of alloys, theoretical calculations have been made relating the solvent diffusion coefficient to the atom jump frequencies in the vicinity of an impurity. On the basis of these calculations, it is possible to infer detailed information about atomic parameters (vacancy jump frequencies, impurity-vacancy binding energies) from the results of macroscopic diffusion measurements.

Kinetic Theory of Whisker Growth.—Numerical solutions for whisker length as a function of time have been obtained for the surface diffusion model of whisker growth. In this model atoms from the vapor strike the sides of the whisker, are adsorbed, and then surface diffuse along the whisker to the whisker tip where they are incorporated into the solid whisker. Of particular interest is a comparison of the exact numerical solution with the steady state approximation, since, if this approximation is valid, only the product, $D\Sigma$, of the surface diffusion constant D and the mean adatom stay time Σ can be determined. Detectable deviations from the steady state approximation are necessary to determine both D and Σ separately. The results indicate that only extremely accurate measurements on whiskers of very small radii can possibly yield values of both D and Σ.

High-Temperature Phase Relations of Niobium and Tungsten Oxides.—The phase diagram was determined of the complex system niobium pentoxide-tungsten trioxide. The phase relations were established using a combination of quenching techniques, microscopic examination and x-ray methods. One region of solid solubility, twelve stable compounds, one metastable compound, and no non-stoichiometric compounds were found.

Properties of Aqueous Salt Mixtures.—A program of water desalinization and purification necessitates a knowledge of the thermodynamic properties of mixed salt solutions and, in particular, how these mixed salt solutions differ from solutions of the separate components. A productive study was undertaken of the properties of mixed salt solutions utilizing accurate isopiestic vapor-pressure measurements. In the two and one-half years during which the project was in effect, seven research papers dealing with the properties of aqueous solutions of the salts present in sea water, singly and in mixtures, were published. Particularly outstanding was the development of a thermodynamic method for studying the behavior of one salt in a mixture containing two or more saline materials.

Soft x-ray Spectrometer.—A high-vacuum grazing incidence, grating spectrometer for soft x-ray spectroscopy has been built and put into operation. Digital electronic recording for automatic data processing is employed. Close control of the specimen temperature can be maintained and the geometry of the electron excitation is such that self-absorption is minimized. The wavelength range of the spectrometer is from below carbon −K at 4.4 nm to about 60 nm with a constant resolution throughout the range of about 0.05 nm. This instrument will be useful in studying the energy distribution of valence electrons in metals and alloys as a function of composition, temperature, and crystal structure which is essential for an understanding of the physical properties.

Nuclear Magnetic Acoustic Resonance.—The first direct acoustic excitation of the Ta^{181} nuclear spin at room temperature was observed for a perovskite structure $KTaO_3$ single crystal. The specimen measured was of very high purity and the transducer was attached to one of the two (100) faces which had been polished optically flat and nearly parallel. A rotational pattern of the resonance was secured by varying the angle between the acoustic axis and the magnetic field. The results indicated that this method is valuable in crystal characterization of the defect structure of a crystal, provided that the specimen size is sufficiently large to minimize any effect due to mode mixing within the acoustic standing wave pattern.

Mössbauer Spectrometer Receives Acceptance.—The latest NBS design of a Mössbauer spectrometer has received considerable attention by U.S. instrument manufacturers. One company has copied the NBS spectrometer and is currently marketing it. Another company has consulted with NBS and has recently come out with a versatile multiscaling pulse height analyzer which is particularly adapted to the NBS spectrometer.

Mössbauer Effect in Titanium-Iron-Cobalt Alloy.—A ferromagnetic titanium-iron-cobalt alloy has been examined by the Mössbauer effect. The results were surprising in that no hyperfine field was detected at the site of the iron nucleus, although there is usually a hyperfine field when the material is ferromagnetic. This result is being interpreted in terms of present knowledge of magnetism.

High-Field Magnetoresistance of Reduced $SrTiO_3$.—The high-field magnetoresistance of reduced $SrTiO_3$ has been measured. This material is both a semiconductor and a superconductor (the latter property was established in 1965 at NBS). In collaboration with scientists at the Naval Research Laboratory, measurements were made in the temperature range 1.4 – 4.2 °K in magnetic fields up to 150 kOe. The

data confirm the theoretical picture of ellipsoidal energy surfaces along the <100> axes and are in excellent agreement with low-field measurements.

Molecular Emission Spectra.—Emission spectra in x-ray fluorescence have been obtained for the four chlorinated derivatives of methane and five chlorinated fluoromethanes in the gas phase. No previous measurements of x-ray emission spectra from molecular gases have been recorded. The spectra of the chloromethanes contain two prominent lines whereas the chlorofluoromethanes show multiple structure of up to four lines. A promising application of these unique data is the construction of energy level systems for these molecules, interpreting the spectra structures in terms of molecular orbital energies.

TECHNICAL ASSISTANCE TO OTHERS

IMR gives technical assistance and advice on materials to other Government agencies, and to science and industry. Arranging conferences and seminars to facilitate dissimination of new data useful in solving materials problems is one of the services provided.

Advisory and Consulting Services

Cooperation With NASA Space Flight Program.—In cooperation with NASA Goddard Space Flight Center Laboratory, the acceptance angles for collimated x-rays of a number of potassium acid phthalate crystals were measured. NASA was also advised on techniques for checking crystal quality. Such crystals are a part of the measurement system of rockets and satellites used to determine solar x-ray spectra.

Magnet Study for Proposed AEC 200-BeV Accelerator.—An analysis of the refrigeration requirements for super-conducting magnets which may be used in the Atomic Energy Commission's proposed 200-BeV accelerator has been made. Approximately 160 magnets will be required in the experimental areas—located outside the accelerator's main ring-like structure—to bond and focus the beams of high-energy charged particles. The refrigeration system for the large number of magnets distributed over great areas will be complex.

The Cryogenic Data Center.—Bibliographic service nearly doubled in the Cryogenic Data Center, primarily due to orders from outside NBS. Nearly one hundred major bibliographies were prepared from custom literature searches of the Center's automated storage and retrieval system. About 60 percent of these were for private industry,

universities, and other Government agencies and foreign laboratories. By the end of the year more than 44,000 accessions had been added into the system, 8,000 of which were processed during the year. The weekly announcement of some 150 to 200 new items of cryogenic literature was put on a subscription basis during the year, with about 700 paid subscriptions received.

Liquefied Natural Gas.—At the request of the Federal Power Commission, a review and critical evaluation of plans and specifications was undertaken for a proposed two billion cubic foot storage facility and associated liquefaction plant to be constructed on Staten Island in New York City. Expert evaluation of the design and opinion concerning the safety of the operation had been solicited because of the considerable volume of flammable liquid involved and the proximity to populated areas.

Bubble Chamber at the Argonne National Laboratory.—Continuing consultative and advisory services were provided to the Atomic Energy Commission during the planning and construction of the proposed 30,000 liter, liquid hydrogen bubble chamber at the Argonne National Laboratory. This will be the world's largest bubble chamber and will advance the U.S. program in high-energy nuclear physics by more effectively utilizing the particle accelerator located at Argonne. A review was recently completed of preliminary plans for safety factors and design characteristics. Evaluation is currently underway on individual design packages.

Underground Corrosion Consultation.—At the request of the Architect of the Capitol, a corrosion survey and inspection was made of underground structural steel supports in connection with construction of an underground garage for the Rayburn House Office Building. The Bureau's consultation on this problem indicated that anticipated anti-corrosion measures would not be needed; this saved a considerable sum of public funds.

Conferences and Symposia

First Annual IMR Symposium.—This was the first of an annual series of Symposia planned by IMR with the objective of improving the effectiveness of research in materials science. This symposium summarized the present capabilities and future potential of the more useful tools for trace characterization of materials. With international participation, the emphasis was placed on the exchange of knowledge and the establishment of effective intercommunication among the various disciplines on which a complete and meaningful trace characterization depends.

Conference on Calculation of the Properties of Vacancies and Interstitials.—Scientists from six countries participated in this conference sponsored jointly by IMR and by the Advanced Research Projects Agency. The meeting dealt with the theory and techniques used in the calculation of the properties of simple point defects in crystals. Topics discussed were: energies of formation, motion, and association of simple defects, lattice configurations near defects, localized electronic and vibrational states, and the scattering by defects of electrons and phonons.

Crystal growth Conference Proceedings Published.—The proceedings of a 1966 Crystal Growth Conference have been published under the editorship of a member of the IMR scientific staff with the collaboration and advice of leading experts from 18 countries and the United States. The proceedings constitute a summary of present knowledge on the mechanisms and techniques of crystal growth. The conference, organized with aid from NBS staff, dealt with the great impact of crystal growth studies on science and technology, their actual and potential use in automation, servo-control, communication, computation, domestic appliances, and almost all chemical, ceramic, and metallurgical processes.

Corrosion Dialogue.—This symposium, which was jointly sponsored by the Office of Naval Research and NBS in cooperation with the Naval Research Laboratory, was designed to bring about a dialogue between workers conducting basic and applied research in the field of aqueous corrosion. Communication between these groups is frequently poor because of diverse points of view and differences in professional goals. A better understanding of the overall problems faced by both groups is essential in working toward eventual solution of individual problems. The symposium attempted to achieve this understanding by presenting widely recognized, representative speakers from both areas and encouraging open discussions among those actively engaged in the aqueous corrosion field.

Fourteenth Feld Emission Symposium.—The Fourteenth Annual Field Emmission Symposium was sponsored jointly by NBS, the Office of Naval Research, and Georgetown University, and held at NBS and Georgetown University. Sixty-eight technical papers were presented dealing with field-electron and field-ion microscopy and related topics. The symposium brought attendees up-to-date on the most recent concepts and developments in the area of field emission.

Symposium on Ceramic Materials.—A one-day symposium on ceramic materials and their properties was held at NBS Gaithersburg. The program, which was intended both for ceramists and for engineers

and scientists whose specialties are in other fields, provided a concise introduction to ceramic materials and their properties.

Open House.—An open house was held for the American Welding Society and the American Society for Metals. The organization and programs of NBS were presented with emphasis on metallurgy. A tour of NBS facilities followed.

Metals Science Field Day.—In cooperation with the Washington Chapter, American Society for Metals (ASM), a Metals Science Field Day at NBS was held on Saturday, January 21, 1967. The Field Day was designed to introduce science teachers and students in the metropolitan Washington area to the world of the metallurgist and the metals scientist. The program featured lectures on metallurgical subjects, a tour of the NBS Metallurgy Division facilities and a panel discussion.

NBS Reactor

The NBS high-flux, tank-type, heavy water moderated reactor is nearing operational status. The reactor will operate initially at 10 megawatts, with an in-pile flux of 10^{14} neutrons per square centimeter per sec. In collaboration with other divisions of NBS, with other Government agencies and with universities, the reactor group will perform research in solid state and chemical physics using the techniques of neutron scattering and diffraction. There will be investigations of the structural and dynamical properties of molecules, crystals liquids, and magnetic materials via neutron elastic and inelastic scattering.

INSTITUTE FOR APPLIED TECHNOLOGY

The basic mission of the Institute for Applied Technology (IAT) is to provide services that support and stimulate the application of science and technology to national needs. In the pursuit of this broad objective, IAT programs are oriented to industry, to the States and regions of the country and to all levels of Government. Program activities are selected which are uniquely appropriate to the NBS mission and primary support is given to those projects in fields of particular competence in the Bureau. The Institute cooperates with industry to facilitate the use of new technology. It provides technical advice and support to Government agencies, concentrating on those areas in which it can provide leadership in applying new technology to Government operations.

The IAT program activities reflect the Institute role as a part of NBS and the national measurement system, and as a participant in the fast-moving national technological scene. The coupling of science and technology with the daily activities of industry, commerce and Government motivates much of the Institute planning and operation. Its activities fall into two major categories—Technological Measurements and Standards, and the Transfer of Technology.

TECHNOLOGICAL MEASUREMENTS AND STANDARDS

This category covers the Institute efforts for the broader extension of the national measurement system into the engineering and technological fields. It is a program to apply principles of good measurement, rather well defined in the science area, to the determination of performance or other significant characteristics of products, systems and devices important either in commerce or to Government needs. In essence, the objective is to find ways by which standards can be developed for items, systems or devices which are not readily evaluated in terms of existing measurement methods.

The key in the development of effective performance standards is the identification of significant criteria which charcaterize the performance of a product, after which the methodology for measuring these criteria is evolved. As the complexity and technical sophistication of articles of commerce increase, it is increasingly difficult to define those characteristics of a product which best measure its performance. Often products are now "systems" and the subjective response of man is also part of the "system." To illustrate this point, one can compare the job of measuring the performance of a radio of 30 years ago and that of measuring the performance of a modern "home-

entertainment center" which includes stereo reproduction of records, tapes, AM–FM radio, and also color television.

The concept of performance criteria as the basis for establishing standards has significant implications in the stimulation of innovation, for it encourages producers to meet the performance required by whatever design of product will do the job. In fact, the idea of performance criteria has ramifications beyond those concerned with articles of commerce. Our national welfare depends critically on making informed decisions related to complex social and economic policies and programs. To do this, one needs to define criteria of performance for these policies and programs and be able to measure or predict possible benefits and costs of alternative action courses. Through the techniques of systems analysis and operations research, technology has provided a means for helping such decision-making.

Institute activities in technological measurements and standards range from the development of performance criteria and test methodology for individual items to the study and analysis of complex systems such as a multi-State transportation network.

Program elements include seven areas:

1. Building Technology
2. Automatic Data Processing
3. Electronics Technology
4. Systems Analysis
5. Motor Vehicle Safety
6. Engineering Materials
7. Industrial and Consumer Products.

BUILDING TECHNOLOGY

Buildings represent over half of the existing tangible wealth of this country. Aside from long-term economic significance, the annual building production is in the range of $100 billion, with an effect in every village, town, and city in the country. Yet this major economic activity has never really entered the mass-production stage of industrialization, and hand craftsmen still play a central role in the construction field. However, climbing building costs are accelerating the move to industrialization of building construction, and this change is already presenting pressing needs for advanced methods of evaluation, and for standardization of test procedures and performance requirements for complex components. The objective of the IAT building technology program is to develop the technological base and evaluative procedures whereby industrial innovation in building systems and components can be used more effectively through the normal building code, standards, and specification process. Laboratory and field support is provided to Federal agencies and State and local Government groups

concerned with building construction and technology. In addition technical consultation and advice are made available to industry and cooperative activities are carried on with private groups which draft, promulgate, and distribute building standards and codes.

Masonry Engineering Design Criteria.—More than 100 masonry wall specimens were tested to failure while measuring their structural behavior. Specimens included brick and concrete block construction fabricated with conventional and modified (high-bond) portland cement mortars. These tests were conducted under simulated actual conditions by subjecting the wall panels to compressive bearing loads and simultaneously applying transverse flexure-producing air pressures or racking loads as would be encountered by buildings exposed to wind pressures. It is expected that this research will contribute substantially to a more rational approach to the design of masonry.

Measuring Structural and Fire Loads in Buildings.—The actual weighing of building contents is at best a very expensive operation, and a pilot study is underway to develop equipment and techniques for less costly methods to obtain the information needed on structural and fire loads of buildings in use. Inexpensive equipment for weighing contents has been developed. Data gathered by actually weighing the contents of an 11-floor building at the Bureau are being analyzed. From the study of this information, which is suitable for automatic data processing, it is expected that statistical sampling techniques and other less expensive evaluative methods can be developed.

Model Study of Air Motion in Rooms.—By introducing a lightweight dust into the air inside a model room, illuminated photographs can be made for observing the air movement and studying its direction and velocity. This technique has been developed as part of an environmental study aimed at learning more about the convective flow of air in rooms, the interchange between rooms, the influence of hot or cold exterior walls or window surfaces on drafts, and air movement through leaking walls. A parallel study is being made to develop an analytical model for predicting these phenomena.

Matching Truck Bodies and Refrigerating Units.—A procedure has been developed for predicting the increased cooling load resulting from one-, two-, or three-minute openings of refrigerated truck doors. This project, jointly sponsored by NBS, the U.S. Department of Agriculture, and the Truck Body and Equipment Association, augments previously reported methods for testing and rating the cooling load of refrigerated vehicles. Knowledge of the door opening cooling loads permits proper matching of truck bodies and refrigerating units. Additional studies of the effect of door openings on cargo temperatures are planned.

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To study the flow of air within and between adjoining rooms, lightweight dust is introduced into a model room and patterns of motion are photographed. The pattern above shows airflow through two narrow openings in a partition. The wall to the far left is heated; that to the far right, cooled.

Engineering Properties of Roofing Systems.—In 1966 about two billion square feet of built-up roofings were applied on public and private structures in the United States. Premature failures of these roofing membranes, attributed to thermal stresses induced by large and sudden temperature changes, can result in costly damage and serious problems for manufacturers, architects, builders, and building owners. Laboratory study of the engineering properties of bituminous built-up roof membranes showed that failures due to thermal shock were related to physical properties such as breaking load in tension, modulus of elasticity, and the coefficient of linear thermal expansion.

Concurrent field investigation of failures was made. From the laboratory work a thermal-shock resistance factor was derived, with values reported for the commonly used membranes covering temperature ranges likely to be encountered by exposed roofs in areas where failures have occurred. A unique approach was used to relate the laboratory meaurements and the behavior of membranes under use conditions in buildings.

Field Burnout Tests of Apartment Dwelling Units.—Information on the effects of fire on modern buildings and materials has been obtained from a series of full-scale burnout tests in an experimental test building. NBS evaluation of the fire performance of the integrated construction was accomplished in a test structure designed by the Pratt Institute School of Architecture under a grant from the Low-Income Housing Demonstration Program of the Housing and Home Finance Agency, now a part of the Department of Housing and Urban Development. Using a wood crib fuel load of 6 lb/ft^2 representing combustible contents, and a structural design load of 40 lb/ft^2 applied to the floor or roof above the fire room, these burnout tests permitted study of the fire effects on floor-wall joints, smoke penetration through doors and openings, and other complex interactions not generally feasible in conventional laboratory fire tests.

Binders in Latex Paint.—Despite the increasing use of latex paints (estimated at 100 million gallons a year), standard methods for identifying, quantitatively determining, and characterizing the polymeric binder portion of such paints have not been established. Such methods are of importance in relating paint performance to binder characteristics and in the development of Government procurement specifications. Bureau chemists devised new or improved methods for separating the polymer portion, identifying it by infrared absorption spectroscopy, and determining its quantity. In another phase of the study, a convenient viscometric technique of suitable precision was derived to determine the molecular weight of vinyl acetate copolymers. This technique can be used in routine laboratory work. Paint properties determined by the molecular weight of the polymer include durability, toughness and resistance to abrasion, water, solvents, and heat.

AUTOMATIC DATA PROCESSING

The Center for Computer Sciences and Technology completed its first full year of operation in fiscal year 1967. Established by a Commerce Department Order in September 1965, it carries out the responsibilities of the Secretary of Commerce under Public Law 89–306 (the Brooks Bill) for broad ADP standards development, consultation, and assistance to Federal agencies and supporting research in matters relating to the use of computers in the Federal

Government. This mission necessitates close interaction with ADP managers in the General Services Administration and the Bureau of the Budget, who share responsibility under the Law for improving the use of computers in Government.

The Center, which has increased its staff during the year, is operating in four areas: ADP standards, consultative and advisory services, research, and computer services. Sizable Federal savings in computer expenditures are anticipated, particularly as the establishment of standards will allow the Government to procure the best qualified equipment for specific tasks, and make objective comparisons of performance claims for "software" output of various manufacturers.

ADP Standards.—There are three major phases in the NBS Federal ADP Standards activity:

1. Project Nomination—determine the need, define the scope, and collect all available information that relates to a specific proposed standard. Major current projects include: time sharing and remote console operation; request for proposal, request for quotation and contract formats; hardware interfaces. Previously reported and continuing are a glossary of ADP terms; data interchange codes; magnetic tape measurement tape techniques.
2. Standards Development—prepare a working draft, resolve controversy over alternatives, coordinate with involved manufacturers, suppliers, Federal users, the Bureau of the Budget and its ADP Advisory Council, and the Interagency ADP Committee. From this activity a consensus is developed.

   Major projects at this stage are: FORTRAN standard reference; COBOL programming language; optical character recognition character set, and standard techniques to facilitate interchange of scientific and technical information.
3. Recommendation—prepare a final draft, and together with historical background and justification materials, forward recommendations to the Secretary of Commerce for his approval and dispatch to the Bureau of the Budget. The Secretary recommended adoption of two Federal ADP standards in fiscal 1967; Standard Code for Information Interchange, and Standard Perforated Tape Code for Information Exchange.

Consultative and Advisory Services.—These services were provided to more than 20 Federal agencies with specific problems in a broad range of subjects. Among the more significant projects were:

1. Feasibility study assistance to determine the need for a computer—National Labor Relations Board.

2. Computer selection assistance—Peace Corps, Civil Service Commission, Department of Labor, Patent Office, National Center for Health Statistics, Bonneville Power Authority.
3. Assistance in improving the operations of existing computer installations—Agency for International Development, Army Map Service.
4. Assistance in basic information system design—Food and Drug Administration, National Institutes of Health, Small Business Administration, Treasury Department, National Center for Radiological Health.
5. Review the effectiveness of existing systems—Naval Oceanographic Office, General Services Administration-Communications Service.
6. Major management and organizational review of ADP activities—Department of Health, Education, and Welfare.
7. Develop special data processing techniques—Patent Office.

In addition to assisting specific agencies with specific problems, the Center is working in areas of general assistance which include:

a. The development of management guidelines for such things as the conduct of feasibility studies, computer selection, and computer performance evaluation. These guidelines will be a product of both research and knowledge gained through the consulting services.
b. Operation of the Technical Information Exchange to provide access for Government agencies to a large and growing store of computer science information and experience data.

Research.—For many years the Bureau has conducted research in computer science fields of particular utility in Government operations. The Center has continued this basic work, and the major projects added this past year include:

1. *File Organization and Segmentation*—to develop theoretical foundations and general practical methods for managing very large data files such as in the National Chemical Information Program.
2. *Generalized Data Base Management Aids*—to design a generic selective information extractor program and report generator program to facilitate the accessing, formatting and output of information elements of large files.
3. *Research on Two-Dimensional Objects*—a linguistic study to solve the problem of automatic processing of two-dimensional information, such as Chinese characters, engineering drawings, chemical structures, and maps.
4. *Chemical and Biological Information Storage and Retrieval*—to develop techniques for automatic handling of information

needed by research workers in drugs, medicine and related fields.

5. *Evaluation of Display Techniques*—to assist in the selection, testing and evaluation of computer activated display techniques for the Naval War College.

Computer Services.—The Computer Services Division of the Center provides computer time and programming within NBS and for many other Government agencies. Until the sharing role was recently assumed by General Services Administration, this Division also operated the Metropolitan Washington Computer Sharing Exchange. Near the end of FY 1967, a Univac 1108 was installed in place of four different machines formerly used.

Services to Federal and Other Agencies.—Data processing services were provided to 70 organizations including 10 executive departments and 25 agencies of the Government, the Congress, State and local governments, quasi-government organizations and universities.

NBS Scientific Programming Support.—Programming and consultative services are provided in support of NBS technical activities. This effort is largely in assisting NBS scientists with problem formulation and in writing FORTRAN programs.

ELECTRONICS TECHNOLOGY

The electronics industry is among the fastest growing and most heavily research-oriented in this country. In the context of R&D funds spent within the industry, NBS activities are relatively small. Yet the Bureau contribution has a broad pervasive influence in the field. Emphasis is placed on the characterization of basic building blocks, that is, acquiring the "nuts and bolts" knowledge needed for advances in the technology. An example of this kind of activity is the effort given to studies of the yield, performance and reliability of discrete and integrated semiconductor devices. The NBS Electronics Instrumentation group, working with materials such as germanium and silicon, develops measurement techniques and test procedures for information on resistivity and lifetime, detection and identification of flaws, control of material properties in processing, and correlation of the properties of devices with materials characteristics. Although funding and staff restrictions have limited Bureau coverage, there has been an expansion in participation with national and international standards groups.

Radiation Damage and Detectors.—Semiconductor nuclear radiation detectors, because of their small size, fast response, low noise and excellent energy resolution, are now used extensively in satellite borne

space radiation experiments. Knowledge of the useful life and changes in the performance of detectors which must operate in the intense fields of the earth's radiation belts is needed when planning space radiation monitoring experiments. NBS in cooperation with NASA-Goddard Space Flight Center is currently studying the effects of protons and electrons, with energies up to one million electron volts, on the performance of silicon nuclear radiation detectors which are commonly used in this field. In addition to knowledge of the useful life of detectors exposed to this radiation, results of the investigation will assist in the development of detectors which are more resistant to the effects of radiation.

New List of Temperature Measurements Information.—A supplement to the *Bibliography of Temperature Measurements* was published during fiscal 1967. It contains 1900 references, thus updating this publication used by scientists and engineers responsible for accurate temperature measurements in R&D projects or production processes. Included are references to thermo-electric, resistance, expansion and radiation devices, as well as those related to theory, calibration, temperature scales, special and nuclear application, associated equipment, and testing procedure.

Performance Criteria for Thermocouples.—A recently completed study of the relative thermoelectric stabilities of platinum-10%-rhodium vs. platinum and platinum-30%-rhodium vs. platinum-6%-rhodium thermocouples has shown the latter to be slightly more dependable. Changes in thermal emf were determined after prolonged heating in air, oxygen, and helium at temperatures up to 160° C. In all cases the Pt-30-Rh/Pt-6-Rh showed slightly greater stability. Heating in oxygen produced the least change in thermal emf in both thermocouples.

SYSTEMS ANALYSIS

In any program for promoting the application of technology to complex problems of industry or Government, the use of systems analysis or operations research is almost a mandatory requirement. The NBS Technical Analysis Division seeks to develop, test and disseminate systems analysis techniques which are applicable to public sector problems in terms of program planning, resource allocation and program execution. Within the civilian agencies of the Government, the IAT systems analysis group is the largest such organization. It serves other agencies in the solution of their specific systems analysis problems, and helps these agencies to develop their own capacity to tackle complex systems problems. It also conducts research on cost-benefit analyses for Government programs.

National Planning Model.—A computer program was written and tested for a large scale Korean AID project. Designed to yield 5-year forecasts for economic planning, the model involves a comprehensive 270 sector breakdown of the Korean economy. This national planning model is one of the most sophisticated in use anywhere in the world.

Search Program for Heavy Metals.—Completed for the U.S. Geological Survey, this evaluation of the costs and probable benefits of a heavy metals search program will provide the Bureau of the Budget with information needed to make a rational funds allocation to this Federal program. The study requires application of geological and economic concepts in a system context.

Patent Application Examination Processing.—In a continuing project with the Patent Office, IAT completed a systems study of the extensive clerical support activities of the patent application examination process. Clerical skills, work habits such as sequencing and task changing practices, psychological environment, and other factors were investigated in terms of their contribution to backlogs and application pendency times. Recommendations included setting priorities for work and changes in organization structure and equipment to facilitate clerical activities. A major objective of the project is to develop Patent Office systems analytic capabilities.

Progress in Transportation Simulation Studies.—Significant progress was made in the development of computer simulation programs in support of the Northeast Corridor Transportation Project of the Department of Transportation. It is now feasible to portray the dynamic flow of passengers over computerized representations of present and future facilities. NBS has contributed methodologies for evaluating and planning intercity transportation systems analogous to the models developed over the years for evaluating urban transportation systems. Variation of loads on facilities can also be simulated, a feature now being applied to urban transport by MIT.

Post Office Mechanization Program.—Contractor efforts under a seven-year mechanization program being developed by the Post Office were evaluated in terms of benefits to general postal operations. The contractor programs for mechanized equipment, mail-handling systems, manual processing of mail, and a simulation procedure for mail processing were reviewed and analyzed.

MOTOR VEHICLE SAFETY

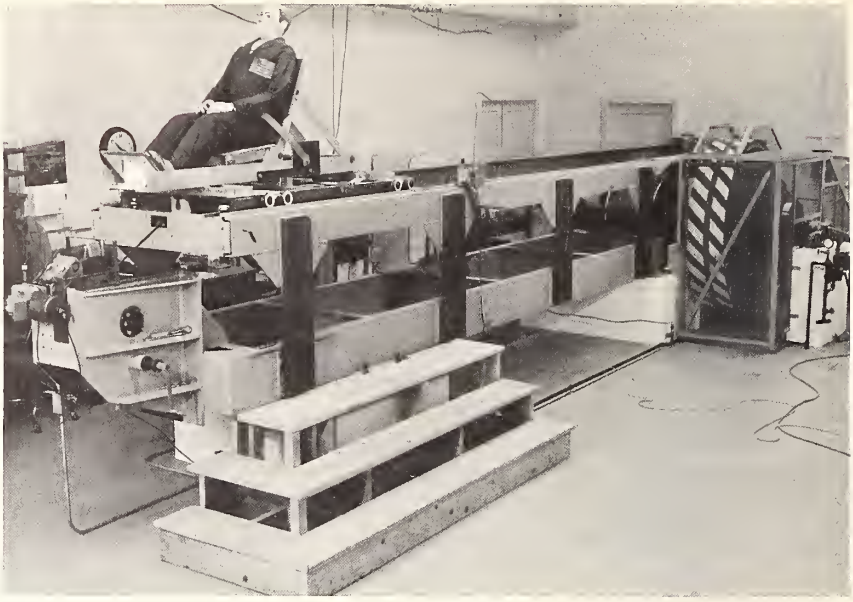
During the last quarter of FY 1967, the Bureau began to provide technical assistance to the National Highway Safety Bureau (NHSB)

of the Department of Transportation in its development of adequate motor vehicle safety performance standards. The Office of Vehicle Systems Research was formed in IAT to conduct the needed research and to develop the technical base for testing and evaluating tire, occupant restraint, and braking systems. NHSB has the responsibility for issuing standards evolving from the NBS recommendations.

Braking Systems.—Studies were made of the types of equipment needed for laboratory testing of complex braking systems and their components. A special purpose inertia brake dynamometer will be installed for testing complete braking systems, and two types of materials testing machines will be used to study the friction properties of brake lining materials. A laboratory was also established for the development and improvement of methods for evaluating the chemical, physical and functional properties of motor vehicle hydraulic brake fluids. In cooperation with committees of the Society of Automotive Engineers and the Chemical Specialty Manufacturers Association, initial progress was made in revising and upgrading existing SAE standards for automotive hydraulic brake fluids, for handling and dispensing fluids, and for service maintenance of fluids in brake actuating systems.

Occupant Restraint Systems.—A research program was initiated in FY 1967 with the Holloman Air Force Base in Alamogordo, N. Mex., for test work with the Daisy Decelerator (employing the use of dummies, as well as human subjects). Tests were made to establish basic parameters for the development of dynamic test standards and results will be used as reference criteria for the NBS dynamic seat belt tester. Tests of 23 human subjects using seat belts and upper torso restraints in the conventional manner at decelerations up to 17 g represents a considerable extension of controlled experimental data. Previous data of human reaction in this configuration were limited to one or two isolated tests at an 8 g level. Two of the dummies which are to be used on the NBS Dynamic Tester were given preliminary performance tests in this program.

Tire Systems Standards.—Basic studies were initiated which will utilize methods of theoretical and applied mechanics to explain the behavior of tires under conditions of use. Correlation between laboratory (wheel method) and road tire behavior is being investigated. Research will be conducted to establish quantitative measures of the characteristics of the tire performance such as tread life or wear, carcass strength, braking and traction capabilities and cornering behavior for the purpose of developing a uniform quality grading system for tires.



"Sam," an anthropomorphic dummy is seated on the dynamic seat belt test machine developed by NBS. The sled is jerked backwards, simulating a forcible stop when going forward. The forces on Sam, his seat belt, and the sled are measured electronically and recorded to determine the restraint required and to test the ability of the seat-belt components to withstand the forces.

ENGINEERING MATERIALS

IAT provides advisory, consultative, and laboratory investigation services relating to selected engineering materials. The laboratory work is mainly for the development of test procedures which can be used by other testing laboratories. The Materials Evaluation Laboratory, responsible for this program, works with national and international groups to establish standards for these materials. Services include establishing a technical base for other Government agencies to set purchase specifications.

Magnetic Tape Characteristics.—In collaboration with NASA, the Bureau has undertaken studies of the physical characteristics, service properties, and chemical stability of magnetic recording tapes in an effort to improve their efficiency and longevity. These tapes play an important role in the space effort, as a means for storing and transmitting data. Not only must tapes perform satisfactorily during the life of a space vehicle, such as an Orbiting Scientific Observatory, but tape recordings on the ground should preserve information for many years.

Government Paper Standards.—Two notable improvements have been made during the past year in the Government's standards for printing papers. These resulted from work done by the Materials Evaluation Laboratory in cooperation with the Specifications Committee of the Congress Joint Committee on Printing. The first relates to standards that now exclude fluorescent brighteners for many classes of papers; this requirement has the aim of making the appearance of the paper in Government publications more uniform. The method of testing for the presence of fluorescent materials uses a filter reflectometer with 0°– 45° geometry, an incandescent light source operating at 3100 °K, a CIEZ (blue) filter, and a movable ultraviolet absorbing filter to permit exclusion or inclusion of the UV component. It was possible to set an instrumental value for maximum fluorescence that gave satisfactory correlation with expert subjective evaluation.

The second improvement results from research by NBS and other laboratories, over many years, which has demonstrated that acidity in paper reduces the useful life of books and archival documents. Recent progress in the paper industry has made it possible for the Government to reduce substantially the amount of acid permitted in most printing papers. Journals, books, and other items printed by the Government can thus be expected to remain in good condition much longer.

Long-Term Storage of Medical Items.—The Public Health Service maintains the Civil Defense Medical Stockpile, at a level of more than $200 million, and consisting of some 400 items of medical supply and equipment in 37 depots and 1800 emergency hospital units in all sections of the country. Since little data relating to the quality of the stockpile was available, the Public Health Service enlisted the aid of the Food and Drug Administration, the Naval Ammunition Depot at Crane, Indiana, and NBS to provide testing services for a comprehensive surveillance program. During the last five years data have been amassed which provide general guidance for storage of medical items and other products of similar composition and components. The Bureau has been concerned with items other than antibiotics, drugs, and pharmaceuticals. The modes of deterioration observed fall into a few well-defined categories. Organic polymers, such as rubber, cellulose, and plastics, show loss in strength properties, decreased elasticity, migration of plasticizer, discoloration, and blooming. Corrosion of metal parts was fairly common in items containing needles and clamps, and in some cases, appeared to be associated with plasticizers in plastic components. Items containing cellulosics, such as bandages, showed decreases in the rate and total amount of moisture absorbed. On the other hand, items containing plaster of Paris exhibited deterioration caused by hydration or water absorption, reflected in increased setting time and decreased strength.

INDUSTRIAL AND CONSUMER PRODUCTS

During 1967 the Institute broadened its efforts to provide improved technical services to the public and to State and Federal Government agencies in product standardization and weights and measures activities. It operated a Testing Laboratory for the General Services Administration's Federal Supply Agency, which conducted work leading to more meaningful specifications for commodities purchased by the Government. Through the Bureau's Office of Weights and Measures various State programs were updated. Product standards were revised by the Office of Engineering Standards Services to meet current needs of the consumer and industry.

Product Standards.—Under the revised procedures for the development of voluntary product standards, amendments to three existing standards were approved and published, and eight standards are ready for publication. The process of developing these voluntary product standards includes circulation of the proposed standard to producers, distributors, users, and consumers who are concerned with the product. During the fiscal year sixteen standards were in this phase of the cycle, 60 proposed standards were started, and 65 existing standards, dating to 1930, were under review to determine the need for revision or withdrawal.

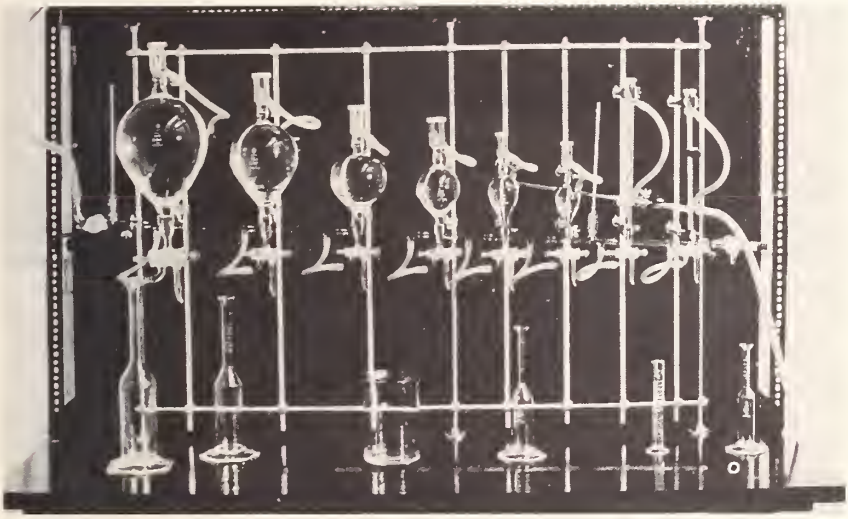
National Conference on Weights and Measures.—The 51st National Conference on Weights and Measures was held in Denver, Colo., July 11–15, 1966. This marked the first time in history of the Conference that a meeting was held outside of Washington, D.C. The principal reason for holding the meeting in the West was to give western officials greater opportunity to attend and participate in Conference matters. The 52nd National Conference returned to the customary Washington meeting place and was held June 26–29, 1967. This meeting provided the first opportunity for Conference Members to inspect the Bureau's new Gaithersburg facilities.

Model Weights and Measures Laboratory.—Due to a great increase in the number of mass, length, and capacity standards calibrations required (over 2,000 such standards which included weights from 10,000 pounds down to 1,000 pounds, volumetric standards from 750 gallons down to precision glassware, and a variety of length standards) to be performed at the Office of Weights and Measures, and because of the increasing requirements of the New State Standards program, a larger and more complete Model State Weights and Measures Laboratory has been constructed at NBS. It is expected that the new lab will be seen by increasing numbers of State visitors as more

and more States begin preparations for constructing their own new facilities.

New State Standards.—A five-year program was initiated in 1965 to provide the 50 States with new standards of mass, length, volume and with precision instruments of measurement to complement them. Laboratories constructed by the States will serve as the measurement center for the States. For the first 10 States, installation of the standards is in the final stages. The standards have been officially presented in dedication ceremonies at Reynoldsburg, Ohio and Springfield, Ill. Standards for the second 10 States are presently being manufactured and deliveries are underway.

The Fair Packaging and Labeling Act.—During FY 1967, steps were taken to organize a staff and to line up the first phases of the new "truth in packaging" program for the NBS responsibility in implementation of the Fair Packaging and Labeling Act of 1966. Although the effective date of the Law is July 1967, it was necessary to develop procedures to determine proliferation in packaged consumer goods. In addition, liaison activities with State and Federal agencies were expanded.



These volumetric standards (automatic pipets and burets calibrated in both metric and U.S. customary units) are part of the complete new set of mass, length and volume standards being provided to each State.

TEXTILE AND APPAREL CENTER

During 1967 IAT closed out the activities of the Center, which was originally funded by the Congress under the Civilian Industrial Technology appropriation. Recognizing the basic difference in methods of operation between the textile and apparel industries, the Center concentrated its efforts on two major projects. For textiles, in anticipation of the technological revolution just starting with the amalagmation of companies, the Center financed the development of an information storage and retrieval system. This consists of a thesaurus to classify the literature, computer programs to operate the system, and indexing of 20 years of textile mechanics literature. The industry is expected to finance the continued operation of the system. For the apparel industry, the Center funded the start of the Apparel Research Foundation, which provides a means to stimulate and educate the industry to invent and innovate. The Foundation publishes a journal which reviews and evaluates new devices, methods, and equipment.

TRANSFER OF TECHNOLOGY

Transfer of Technology may be defined as that process whereby means are devised and applied for stimulating new technologies, channeling them in promising useful directions, and exploiting their use for purposes other than those for which they were originally developed. Within IAT, this process is promoted by programs encompassing the act of invention, the conversion of inventions to commercially viable items through innovation, and the dissemination of technical information to the R&D community.

INVENTION AND INNOVATION

The Office of Invention and Innovation is the Institute activity which helps to develop an environment conducive to technological change. Its basic program has three phases: providing a national basis for formulation of climate-setting federal policies; offering assistance to inventors; and education.

Panel on Invention and Innovation.—Consisting of outstanding business and academic leaders, the Panel was created by the Secretary of Commerce in response to the President's directive to explore new ways for "speeding the development and spread of new technology." The Panel studied the effect of taxation, finance and competition on invention and innovation and issued its findings and recommendations in a report "Technological Innovation—Its Environment and Management." The report was presented to the President, members of Congress, interested Federal agencies, professional groups and international bodies including NATO.

Education in Techniques of Invention and Innovation.—The Bureau and selected universities are exploring what opportunities might be promoted for teaching the techniques of invention and innovation. The program started from recommendations of the National Inventors Council and at this stage its principal activity is the preparation of design cases, based on real problems, for use in engineering curriculae.

Invention Expositions.—The number of States holding invention expositions in fiscal 1967 more than doubled over the previous year: 21 States had at least one such meeting. The expositions are usually run by State organizations to facilitate the licensing, development, and exploitation of new technology by helping to get inventions into commercial use. NBS provides counsel and expert assistance in planning and running the expositions. Publication of an article by the Vice President on the need for inventive skill gave impetus to the program.

National Inventors Council.—The Council, which consists primarily of outstanding inventors, prepared a report for the President's Commission on the Patent System which analyzed the system from the inventor's viewpoint. The Council is concerned with the invention process, the work of inventors, and ways to provide assistance to them through State, regional, and Federal invention programs.

THE CLEARINGHOUSE

A second major activity of the Transfer of Technology category is the IAT program for the dissemination of technical information. This program centers around the Clearinghouse for Federal Scientific and Technical Information which is the central point of contact in the Federal Government for disseminating the results of Government-sponsored R&D to industry, commerce, and the general public. In addition to the Clearinghouse, the Institute maintains certain specialized technical information centers covering engineering standards, weights and measures, instrumentation, and computer sciences.

The work load and output of the Clearinghouse increased substantially during FY 1967. The two Clearinghouse journals (*U.S. Government Research and Development Reports* and *Technical Translations*) announced 33,000 and 19,000 titles, respectively. The title collection in the Clearinghouse now numbers 510,000 which is an increase of almost 12 percent over fiscal 1966. In addition, the Clearinghouse distributed over 2 million copies of research reports.

Document Order Processing.—A unit price/coupon system for paper and microfiche copies of documents was established to provide faster, more efficient service on document requests. Clearinghouse documents with a few exceptions now have a single price, $3.00 for hard copy and

$0.65 for microfiche. The prepaid coupon is the customer's method of payment, order form, shipping label, and receipt of sale. The coupon expedites order handling and shipment.

Fast Announcement Service.—The Fast Announcement Service (individual announcements of significant selected new documents, grouped by industrial interest categories) was changed from a free to a paid service. For an annual charge of $5.00 subscribers may receive announcements in any or all of 57 subject categories.

Descriptive Cataloging of Documents.—The Clearinghouse played a major role in the preparation of the Government-wide *Standard for Descriptive Cataloging of Government Scientific and Technical Reports.* This standard, approved by the Committee on Scientific and Technical Information (COSATI) of the Federal Council for Science and Technology, provides rules to be used for documentative lists in Federal agencies in an effort to gain consistency in catologing.

Announcement Journals.—Major changes and improvements were made in the format, preparation, sales, and distribution of *U.S. Government Research and Development Reports* (*USGRDR*), *Government Wide Index to Federal Research and Development Reports* (*GWI*), and *Technical Translations* (*TT*). The Clearinghouse now sells and distributes the three publications formerly sold and distributed by the Superintendent of Documents. *USGRDR* is now completely computer-produced using Linofilm equipment at the Government Printing Office. The format of *USGRDR* was improved to make the journal more readable and the two sections for DoD and non-DoD reports were consolidated into a single subject sequence.

New Document Input.—The Clearinghouse expanded its Federal agency coverage in acquisitioning technical information. New material was acquired from HUD on mass transportation research; the Labor Department on manpower, automation, and training; San Francisco Rapid Transit Authority on area transportation developments. Census import/export data are available for the first time on a subscription basis. Special economic data reports are also sold by the Clearinghouse as part of the Commerce Department's general program to make more international marketing information available quickly to more businessmen.

APPENDIXES

ORGANIZATION OF THE NATIONAL BUREAU OF STANDARDS*

The Bureau is headed by a Director who is appointed by the President with the advice and consent of the Senate. The Director is assisted in the overall management of the Bureau by a Deputy Director. In addition, there are two Associate Directors and an Executive Officer for Boulder (Colorado) Support who are responsible for the planning and operation of various technical and administrative management services in support of the Bureau's technical programs.

Technical program activities are conducted in organizational units known generally as Institutes. Each is headed by an Institute Director who is responsible for the development and direction of research programs and central national services essential to the fulfillment of a broad segment of the Bureau's mission. These major organizational units are

(1) The Institute for Basic Standards, which includes 13 divisions (4 in Boulder, Colo.), each serving a classical subject matter area of science and engineering;

(2) The Institute for Material Research, which consists of 7 divisions (1 in Boulder, Colo.), organized primarily by technical field; and

(3) The Institute for Applied Technology, which includes 11 divisions oriented to high-technology industries.

DIRECTOR
Allen V. Astin

DEPUTY DIRECTOR
I. C. Schoonover

Assistant to the Deputy Director

P. H. Kratz

OFFICE OF THE DIRECTOR
Assistants to the Director

G. E. Auman
C. N. Coates

Legal Advisor
A. J. Farrar

*As of June 30, 1967.

277-070 O—67——8

Office of Industrial Services

George S. Gordon, Acting**

Office of Public Information

A. V. Gentilini

Associate Director for Academic Liaison

S. Silverman

Office of Engineering Standards Liaison and Analysis

A. A. Bates, Acting**

Office for Program Development and Evaluation

R. D. Huntoon, Acting**

SENIOR RESEARCH FELLOWS

C. Eisenhart
K. Shuler
S. N. Alexander

OFFICE OF ASSOCIATE DIRECTOR FOR ADMINISTRATION

R. S. Walleigh

Deputy Associate Director

P. H. Schrader

Patent Advisor

D. Robbins

Accounting	J. P. Menzer
Administrative Services	G. W. Knox
Budget and Management	J. E. Skillington
Internal Audit	H. F. Whittington
Personnel	G. R. Porter
Plant	H. Graham
Supply	G. B. Kefover

EXECUTIVE OFFICER FOR BOULDER SUPPORT†

S. W. J. Welch

Administrative Services	B. F. Betts, Acting
Instrument Shops	R. S. Perrill
Plant	E. A. Yuzwiak

**As of July 1, 1967.
†Located in Boulder, Colo.

OFFICE OF ASSOCIATE DIRECTOR FOR TECHNICAL SUPPORT

Vacant

Coordinator of Special International Programs	L. L. Marton
Office of Technical Information and Publications	W. R. Tilley
Research Information	Vacant
Office of Radiation Safety	A. Schwebel
Instrument Shops	F. P. Brown
Measurement Engineering	G. F. Montgomery

INSTITUTE FOR BASIC STANDARDS

Director

M. B. Wallenstein, Acting**

Deputy Director
M. B. Wallenstein

Deputy Director for Radio Standards
J. M. Richardson

Coordinator for Measurement Services
H. L. Mason

Office of Standard Reference Data ---------- E. L. Brady
- Nuclear Data
- Thermodynamic and Transport
- Chemical Kinetics Data
- Colloid and Surface Data
- Information Systems Design
- Information Services Data File

Applied Mathematics ---------- E. W. Cannon
- Numerical Analysis
- Statistical Engineering
- Mathematical Physics
- Operations Research

Electricity ---------- C. H. Page
- Resistance & Reactance
- Electrochemistry
- Electrical Instruments
- Magnetic Measurements
- High Voltage
- Absolute Electrical Measurements

Metrology ---------- A. G. McNish
- Optics Metrology Branch
  - Photometry
  - Image Optics and Photography
  - Colorimetry and Spectrophotometry
  - Radiometry
- Length Metrology Branch
  - Length
  - Engineering Metrology
- Mass and Volume Branch
  - Mass and Volume

** As of July 1, 1967.

Mechanics---B. L. Wilson

Sound

Engineering Mechanics

Rheology

Mechanical Measurements Branch

Pressure Measurements

Vacuum Measurements

Vibration Measurements

Humidity Measurements

Fluid Mechanics Branch

Fluid Meters

Hydraulics

Aerodynamics

Heat---R. P. Hudson

Heat Measurements

Cryogenic Physics

Equation of State

Statistical Physics

Molecular Energy Levels

Temperature

Radiation Thermometry

Atomic Physics---K. G. Kessler

Spectroscopy

Infrared and Microwave Spectroscopy

Far Ultraviolet Physics

Electron Physics

Atomic Physics

Plasma Spectroscopy

Physical Chemistry---R. E. Ferguson

Thermochemistry

Surface Chemistry

Elementary Processes

Mass Spectrometry

Photo Chemistry

Radiation Chemistry

Laboratory Astrophysics†---L. M. Branscomb

Radiation Physics---R. S. Caswell, Acting

Radiation Theory

Radiological Physics Branch

X-ray Physics

Dosimetry

X-ray Standards

Nuclear Physics Branch

Radioactivity

Neutron Physics

Photonuclear Physics

Nuclear Spectroscopy

Accelerator Branch

Accelerator Engineering

Radiation Physics Instrumentation

Accelerator Physics

Radio Standards Laboratory†---H. M. Altschuler, Acting

Radio Standards Physics†---Y. Beers

Frequency-Time Dissemination Res.

Frequency-Time Broadcast Services

Radio and Microwave Materials

Atomic Frequency & Time Stds.

Quantum Electronics

Radio Plasma

Radio Standards Engineering†---C. M. Allred, Acting

HF Calibration Services

HF Electrical Standards

HF Impedance Standards

Microwave Calibration Services

Microwave Circuit Standards

Electromagnetic Fields Standards

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†Located at Boulder, Colo.

INSTITUTE FOR MATERIALS RESEARCH

Director

H. E. Sorrows, Acting**

Assistant to the Director

H. E. Sorrows

Office of Standard Reference Materials—W. W. Meinke

Analytical Chemistry—W. W. Meinke

- Radiochemical Analysis
- Spectrochemical Analysis
- Electrochemical Analysis
- Analytical Coordination Chemistry
- Microchemical Analysis
- Analytical Mass Spectrometry
- Organic Chemistry
- Activation Analysis
- Separation and Purification

Polymers—J. D. Hoffman

- Polymer Dielectrics
- Polymer Chemistry
- Polymer Crystal Physics
- Molecular Properties
- Dental Research
- Polymer Characterization
- Polymer Interfaces
- Thermophysical Properties

Metallurgy—E. Passaglia

- Engineering Metallurgy
- Alloy Physics
- Lattice Defects and Microstructures
- Corrosion
- Metal Physics
- Eletrolysis and Metal Deposition
- Crystallization of Metals

Inorganic Materials—E. Ambler

- Inorganic Chemistry
- Inorganic Glass
- High Temperature Chemistry
- Crystal Chemistry
- Physical Properties
- Crystallography
- Solid State Physics

Reactor Radiations—C. O. Muehlhause

- Technical Support
- Reactor Operations
- Reactor & Experimental Engineering Services
- Neutron-Nuclear Physics

Neutron Solid-State Physics

Cryogenics†—B. W. Birmingham

- Cryogenic Technical Services
- Cryogenic Data Center
- Cryogenic Properties of Solids
- Properties of Cryogenic Fluids
- Cryogenic Systems
- Cryogenic Metrology
- Cryogenic Fluid Transport Processes

INSTITUTE FOR APPLIED TECHNOLOGY

Director

J. P. Eberhard

Deputy Director

L. M. Kushner

Materials Evaluation Laboratory—R. B. Hobbs

- Materials Evaluation and Testing
- Procurement Systems
- Evaluation Criteria
- Performance Research

**As of July 1, 1967.

†Located in Boulder, Colo.

NBS/GSA Laboratory——P. J. Franklin
Manager, Engineering Standards——M. W. Jensen
Office of Engineering Standards Services——D. R. Mackay
Office of Weights and Measures——M. W. Jensen
Office of Invention and Innovation——D. V. DeSimone
- Innovation Studies and Analyses
- Invention Programs

Office of Vehicle Systems Research——P. J. Brown
- Tire Systems
- Braking Systems
- Occupant Restraint Systems

Clearinghouse for Federal Scientific and Technical Information——B. M. Fry
- Document Distribution and Reproduction Branch
- Automated Systems and Services Branch
- Administrative Operations Branch
- Joint Publications Research Service
- Document Processing Branch

Building Research——J. R. Wright, Acting**
- Structures
- Materials and Composites
- Fire Research
- Codes and Standards
- Environmental Engineering
- Building Systems

Electronic Instrumentation——M. G. Domsitz
- Engineering Electronics
- Basic Instrumentation
- Electron Devices

Textile and Apparel Technology Center——F. C. Brenner
Technical Analysis Division——W. E. Cushen
- Program Areas: Corridor and Highway Studies
  Systems Analysis and Human Factors
  Economic Analysis
  Development of New Methodology

Center for Computer Sciences and Technology——H. R. J. Grosch
- Office for Information Processing Standards——J. Wegstein
- Technical Information Exchange——M. R. Fox
- Computer Services——I. V. Voltin
- Management Applications Planning——T. P. Parker
- Systems Research and Development——E. Marden
- Information Processing Technology——J. Nigro
- Information Sciences——Vacant

FIELD ESTABLISHMENTS

Institute for Basic Standards

Metrology Division Field Station:
- Visual Landing Aids Field Laboratory — Arcata, Calif.

Radio Standards Laboratory Field Stations:
- Standard Frequency Station WWV–WWVL–WWVB — Fort Collins, Colo.
- Standard Frequency Station WWVH — Maui, Hawaii

Laboratory Astrophysics Division Field Station:
- Poor Man's Relief Mine, Four-Mile Canyon — Boulder, Colo.

Institute for Applied Technology

Office of Weights and Measures Field Stations:
- Master Railway Track Scale Depot — Clearing, Ill.

**As of July 1, 1967.

SUMMARY OF NBS STAFF AS OF JUNE 30, 1967

	Washington	Boulder	Total
Full-time permanent staff [1]	2, 995	617	3, 612
Other staff [2]	311	75	386
Total paid staff	3, 306	692	3, 998
Research associates—guest workers	128	71	199
Total NBS staff	3, 434	763	4, 197
Professional Staff With Academic Degrees:			
Physicists	397	114	511
Chemists	283	9	292
Engineers	172	93	265
Mathematicians	52	9	61
Other	146	4	150
Total	1, 050	229	1, 279

[1] Includes Post Doctoral Research Fellows.
[2] Summer, YOC, Part-Time, Intermittent and Temporary Limited.

FINANCIAL DATA FOR FISCAL YEAR 1967

Program and source of financing	*Obligations incurred in thousands of dollars (rounded)*
Supported by NBS Appropriations	
Operating programs:	
Research and technical services	$30, 768
Civilian industrial technology	155
Special foreign currency program	204
Construction and facilities programs:	
Plant and facilities	1, 429
Construction of facilities	4, 236
Total obligations, NBS appropriations	36, 792
Supported by other funds [1]	
From other Federal agencies	23, 340
From other sources	3, 787
Total obligations, other funds	27, 127
Total program	63, 919

[1] Work supported by other funds consists of research and development programs for other Government agencies; consultative, advisory, and technical services, the performance of various tests and calibrations, and the manufacture and sale of standard reference materials for other Government agencies and the public.

ADVISORY COMMITTEES

STATUTORY VISITING COMMITTEE

Reports annually to Secretary of Commerce on NBS activities. Dates indicate expiration of appointment.

Dr. E. R. Piore, Vice President, Research and Engineering, International Business Machines Corporation (1967), Chairman
Dr. Elmer W. Engstrom, President, Radio Corporation of America (1968)
Dr. Paul C. Cross, President, Mellon Institute (1969)
Prof. Norman F. Ramsey, Department of Physics, Harvard University (1970)
Dr. Robert L. Sproull, Vice President Academic Affairs, Cornell University (1971)

TECHNICAL ADVISORY PANELS

During the past year the National Academy of Sciences-National Academy of Engineering, National Research Council, continued to provide technical advice to the Bureau. Twenty-two panels were in existence. Of the twenty-two panels, fifteen met at least once, the Institute for Applied Technology panel met three times, Building Research panel met four times and the Center for Computer Sciences and Technology panel met two times.

Institute for Basic Standards

Advisory Panel to Institute for Basic Standards
Dr. Ralph A. Sawyer, National Bureau of Standards, Chairman
Prof. Francis J. Anscombe, Yale University
Dr. William G. Amey, Leeds & Northrup Company
Dr. J. H. Webb, Eastman Kodak Company
Prof. R. S. Beitler, American Society of Mechanical Engineering
Prof. John Ross, Massachusetts Institute of Technology
Dr. Wade L. Fite, University of Pittsburgh
Dr. Norman D. Coggeshall, Gulf Research & Development Company
Dr. Bruce H. Billings, Aerospace Corporation
Dr. Peter T. Demos, Massachusetts Institute of Technology
Dr. George Birnbaum, North American Aviation Science Center
Mr. C. E. White, AVCO Corporation

Advisory Panel to Applied Mathematics Division
Prof. Francis J. Anscombe, Yale University, Chairman
Prof. Philip J. Davis, Brown University
Prof. Charles R. DePrima, California Institute of Technology
Dr. Ralph E. Gomory, International Business Machines Corp.
Dr. J. P. LaSalle, Brown University
Dr. J. Barkley Rosser, Harvard University
Prof. John Todd, California Institute of Technology
Prof. John W. Tukey, Princeton University

Advisory Panel to Electricity Division
Dr. William G. Amey, Leeds & Northrup Company, Chairman
Dr. Richard M. Bozorth, International Business Machines Corp.
Prof. Raymond M. Fuoss, Yale University
Prof. George B. Hoadley, North Carolina State University

Dean R. B. Lindsay, Brown University
Mr. E. C. Starr, U.S. Department of Interior
Mr. Douglas C. Strain, Electro Scientific Industries, Inc.
Prof. John G. Trump, Massachusetts Institute of Technology

Advisory Panel to Metrology Division
Dr. J. H. Webb, Eastman Kodak Company, Chairman
Prof. Isay A. Balinkin, University of Cincinnati
Dr. Alsoph H. Corwin, The Johns Hopkins University
Mr. C. L. Crouch, Illuminating Engineering Society
Mr. A. M. Dexter, Bausch & Lomb Incorporated
Dr. Robert E. Hopkins, University of Rochester
Mr. Louis Polk, Dayton, Ohio
Mr. Eric J. Schneider, Engis Equipment Company
Prof. John Strong, The Johns Hopkins University

Advisory Panel to Mechanics Division
Prof. S. R. Beitler, American Society of Mechanical Engineering, Chairman
Prof. Lynn S. Beedle, Lehigh University
Dr. B. B. Dayton, Consolidated Vacuum Corp.
Prof. Cyril M. Harris, The Columbia University
Prof. Arthur T. Ippen, Massachusetts Institute of Technology
Dr. Harry F. Olson, Radio Corporation of America
Dr. M. E. Shank, Pratt & Whitney Aircraft
Prof. R. S. Rivlin, Lehigh University

Advisory Panel to Heat Division
Prof. John Ross, Massachusetts Institute of Technology, Chairman
Prof. G. B. Benedek, Massachusetts Institute of Technology
Prof. Howard W. Emmons, Harvard University
Prof. H. R. Griem, University of Maryland
Dr. E. F. Hammel, University of California
Dr. Paul G. Klemens, Westinghouse Research Laboratories
Dr. John P. McCullough, Mobil Oil Corp.
Prof John G. Phillips, University of California

Advisory Panel to Atomic Physics Division
Dr. Wade L. Fite, University of Pittsburgh, Chairman
Prof. C. O. Alley, University of Maryland
Prof. R. Grant Athay, High Altitude Observatory
Prof. Kurt Dressler, Princeton University
Dr. Leo Goldberg, Harvard College Observatory
Prof. Richard C. Lord, Massachusetts Institute of Technology
Prof. Robert Novick, Columbia University
Prof. W. E. Spicer, Stanford University

Advisory Panel to Physical Chemistry Division
Dr. Norman D. Coggeshall, Gulf Research & Development Company, Chairman
Prof. Kyle D. Bayes, Cambridge, Massachusetts
Dr. Hartwell F. Calcote, AeroChem Research Laboratories, Inc.
Prof. Robert Gomer, The University of Chicago
Dr. Joseph O. Hirschfelder, University of Wisconsin
Prof. Harold S. Johnston, University of California
Prof. B. S. Rabinovitch, University of Washington
Dr. Bruno J. Zwolinski, Texas A&M University

Advisory Panel to Laboratory Astrophysics Division

Dr. Bruce H. Billings, Aerospace Corp., Chairman
Prof. W. R. Bennett, Jr., Yale University
Dr. Wade L. Fite, University of Pittsburgh
Dr. Leo Goldberg, Harvard College Observatory
Dr. Arthur Kantrowitz, AVCO Corp.
Dr. A. Keith Pierce, Kitt Peak National Observatory
Dr. O. C. Wilson, California Institute of Technology
Dr. John A. Hornbeck, Sandia Corp.

Advisory Panel to Radiation Physics Division

Dr. Peter T. Demos, Massachusetts Institute of Technology, Chairman
Dr. John S. Blair, University of Washington
Mr. Casimer J. Borkowski, Oak Ridge National Laboratory
Dr. Marshall R. Cleland, Radiation Dynamics, Inc.
Dr. Charles J. Mullin, University of Notre Dame
Dr. George F. Pieper, National Aeronautics and Space Administration
Dr. W. C. Roesch, Battelle-Northwest
Prof. E. F. Shrader, Case Institute of Technology

Advisory Panel to Radio Standards Engineering Division

Dr. George Birnbaum, North American Aviation Science Center, Chairman
Dr. Paul D. Coleman, University of Illinois
Prof. E. U. Condon, Joint Institute for Laboratory Astrophysics
Dr. Cullen M. Crain, The Rand Corp.
Prof. H. A. Haus, Massachusetts Institute of Technology
Dr. C. Lester Hogan, Motorola, Inc.
Dr. E. W. Houghton, Bell Telephone Laboratories
Mr. Frank McGinnis, Sperry Gyroscope Company
Prof. Arthur A. Oliner, Polytechnic Institute of Brooklyn
Dr. Bernard M. Oliver, Hewlett-Packard Company
Mr. Theodore S. Saad, Sage Laboratories, Inc.
Prof. J. H. Van Vleck, Harvard University

Advisory Committee on Calibration and Measurement Services

Mr. C. E. White, AVCO Corp., Chairman
Dr. William G. Amey, Leeds and Northrup Company
Mr. Marvin Friedland, Eau Gallie, Florida
Mr. John R. Van De Houten, Aerojet General
Mr. S. C. Richardson, General Electric Company
Mr. Bruno O. Weinschel, Weinschel Engineering
Mr. A. J. Woodington, Manager, General Dynamics/Astronautics

Institute for Materials Research

Advisory Panel to Institute for Materials Research

Dr. Robert L. Sproull, Cornell University, Chairman
Dr. William O. Baker, Bell Telephone Laboratories
Prof. John Bardeen, University of Illinois
Dr. Arthur Bueche, General Electric Research Laboratory
Dr. Joseph E. Burke, General Electric Research Laboratory
Dr. Raymond F. Boyer, Dow Chemical Company
Prof. L. B. Rogers, Purdue University
Prof. Roman Smoluchowski, Princeton University

Advisory Panel to Analytical Chemistry Division

Prof. L. B. Rogers, Purdue University, Chairman
Prof. Clark E. Bricker, University of Kansas
Mr. M. D. Cooper, General Motors Corp.
Dr. Edward C. Dunlop, E. I. DuPont de Nemours & Co.
Dr. N. B. Hannay, Bell Telephone Laboratories, Inc.
Prof. George Morrison, Cornell University
Prof. Charles N. Reilley, University of North Carolina
Dr. James White, Oak Ridge National Laboratory

Advisory Panel to Polymers Division

Dr. Raymond F. Boyer, Dow Chemical Company
Dr. C. M. Blair, Union Carbide Corp.
Dr. J. J. Hermans, Chemstrand Research Center
Dr. Fraser P. Price, General Electric Research Laboratory
Dr. William P. Slichter, Bell Telephone Laboratories
Prof. Walter Stockmayer, Dartmouth College
Dr. Howard W. Starkweather, Jr., E. I. DuPont de Nemours & Co.
Prof. Bruno H. Zimm, University of California

Advisory Panel to Metallurgy Division

Prof. Roman Smoluchowski, Princeton University, Chairman
Dr. Walter A. Dean, Aluminum Company of America
Dr. G. J. Dienes, Brookhaven National Laboratory
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Advisory Panel to Inorganic Materials Division

Dr. Joseph E. Burke, General Electric Research Laboratory, Chairman
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Institute for Applied Technology

Advisory Panel to Institute for Applied Technology

Prof. C. West Churchman, University of California, Chairman
Mr. Kenneth C. Allen, Hobart Manufacturing Company
Dr. William W. Eaton, Washington, D.C.
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Dr. Robert A. Hechtman, McLean, Virginia
Dr. Carl H. Madden, U.S. Chamber of Commerce
Dean Joseph R. Passonneau, Washington University
Prof. Philip Morse, Massachusetts Institute of Technology
Dr. Leon Podolsky, Pittsfield, Massachusetts
Mr. Jacob Rabinow, Bethesda, Maryland
Mr. Paul Strassmann, National Dairy Products Corp.
Dr. Michael Witunski, St. Louis, Missouri

Advisory Panel to Building Research Division

Dr. Robert A. Hechtman, McLean, Virginia, Chairman
Mr. James H. Binns, Armstrong Cork Company
Mr. E. N. Davis, Underwriters' Laboratories, Inc.
Dr. J. V. Fitzgerald, Tile Council of America, Inc.
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Mr. Alwin B. Newton, Borg-Warner Corp.
Mr. Raymond C. Reese, Toledo, Ohio
Dean Charles E. Schaffner, Polytechnic Institute of Brooklyn
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Mr. Charles H. Topping, E. I. DuPont de Nemours & Company
Mr. T. E. Werkema, The Dow Chemical Company

Advisory Panel to Electronic Instrumentation Division

Dr. Leon Podolsky, Pittsfield, Massachusetts, Chairman
Mr. J. A. Caffiaux, Electronic Industries Association
Mr. Ralph E. Clarridge, IBM Corporation
Mr. Ivan G. Easton, General Radio Company
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Dr. Richard C. Webb, Colorado Instruments, Inc.

Advisory Panel to Technical Analysis Division

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Prof. Russell L. Ackoff, University of Pennsylvania
Prof. George B. Dantzig, Stanford University
Mr. Martin L. Ernst, Arthur D. Little, Inc.
Prof. Merrill M. Flood, Pacific Palisades, California
Prof. John Meyer, Harvard University
Dr. Hugh J. Miser, The Travelers Research Center, Inc.
Mr. David Novick, The Rand Corporation
Prof. Thornton L. Page, Wesleyan University
Dr. George Pettee, Research Analysis Corp.
Prof. Gustave J. Rath, Northwestern University
Prof. R. F. Rinehart, U.S. Naval Postgraduate School

Advisory Panel to Center for Computer Sciences and Technology

Dr. William W. Eaton, Washington, D.C., Chairman
Mr. John Diebold, The Diebold Group, Inc.
Prof. R. M. Fano, Massachusetts Institute of Technology
Mr. Robert B. Forest, DATAMATION Magazine
Prof. Walter F. Frese, Harvard University
Dr. Cuthbert C. Hurd, Computer Usage Company, Inc.

Mr. James D. Gallagher, McCall Corporation
Dr. Adrian McDonough, University of Pennsylvania
Dr. Jack Moshman, EBS Management Consultants, Inc.
Dr. Charles A. Phillips, Business Equipment Manufacturers Assoc.
Prof. Alan J. Rowe, University of Southern California
Prof. John Tukey, Princeton University
Dr. Willis H. Ware, The Rand Corporation

AWARDS AND HONORS

Recognition of the Bureau's contributions to science and technology often takes the form of awards and honors from Government, academic, professional, and industrial groups. The following list reflects such recognition bestowed on Bureau staff members during fiscal year 1967:

Recipient	*Award*
Achenbach, Paul R.	Distinguished Service Award from American Society of Heating, Refrigerating, and Air Conditioning Engineers Inc.
Bartky, Ian R.	Career Education Award from National Institute of Public Affairs.
Bekkedahl, Norman P.	Charles Goodyear Medal of the Division of Rubber Chemistry of the American Chemical Society.
Bender, Peter L.	Arthur S. Flemming Award.
Branscomb, Lewis M.	Samuel Wesley Stratton Award.
Cook, Robert T.	Creative Communications Award, Department of Commerce.
Diller, Dwain E.	Boulder Scientist Award of the Boulder Chapter of the Scientific Research Society of America.
DiMarzio, Edmund A.	High-Polymer Physics Prize, American Physical Society.
Ellinger, George A.	Award of Merit from American Society for Testing and Materials.
Houston, Dale J.	Career Education Award from National Institute of Public Affairs.
Howard, Robert E.	Fulbright Fellow (India).
Jensen, Malcolm W.	Edward B. Rosa Award.
Kruger, Jerome	Blum Award of the National Capitol Section of the Electrochemical Society.
Paffenbarger, George C.	American Academy of Achievement Award.
Schiefer, Herbert F.	Award of Merit from American Society for Testing and Materials.
Sweeney, W. T.	Certificate of Merit from the American College of Dentists.
Tauber, Stephen J.	Princeton Fellowship in Public Affairs.
Taylor, Dorothy W.	Better Service to the Public Award.
Teal, Gordon K.	American Academy of Achievement Award.
	Inventor of the Year Award from Patent, Trademark, and Copyright Research Institute, George Washington University.
Washer, Francis E.	Talbert Abrams Award from American Society of Photogrammetry.

Department of Commerce Exceptional Service Awards
(Gold Medal)

Recipient	*Technical Area*
Beckett, Charles W.	Thermodynamic properties of materials.
Hague, John L.	NBS Standard Reference Materials Program.
Jones, Sarah Ann	Leadership of NBS library.
Passaglia, Elio	Polymer physics.
Romanoff, Melvin	Underground corrosion of metals.
Taylor, John K.	Materials characterization.
Walleigh, Robert S.	Direction of NBS move to Gaithersburg.

Department of Commerce Meritorious Service Awards
(Silver Medal)

Armstrong, George T.	Thermodynamics, application of fluorine to reaction calorimetry.
Auman, George E.	Development of superior scientific personnel in Federal laboratories.
Ausloos, Pierre J.	Radiation chemistry program.
Campbell, Paul G.	Photooxidation of asphalt.
Cook, Herbert D.	Instrumentation system for rapid automatic calibration of line scales.
Deslattes, Richard D.	X-ray physics.
Graham, Hylton	Planning of Gaithersburg facilities.
McNesby, James R.	Vacuum ultraviolet photochemistry and lamps of high spectral purity.
Penner, Samuel	Magneto-optical design.
Persson, Karl-Birger	Plasma mechanisms and measurements.
Schwerdtfeger, William, J.	Corrosion testing techniques and cathodic protection criteria.
Smith, Scott W.	Calibration and testing of radiation instruments and sources required by user laboratories.
Spijkerman, Jon J.	Instrumentation and standardization of Mossbauer spectrometry.

Department of Commerce Superior Service Award
(Bronze Medal)

Drissel, Winfield L.	Performance in Instrument Shops.
Lewis, Edith Carol	Personnel operations.
McAuliff, Rita C.	Directing calibration services.
Moffitt, Josephine K.	Developing and operating the Electron Device Information Service.
Paulson, Rolf A.	Microchemistry.
Queen, George O.	Ceramics and metallurgy.
Roberts, Aaron G.	Physical methods of evaluation, particularly in organic coatings.
Smith, Dale L.	Electroforming and plating.
Tallerico, John B.	Financial management.

EDUCATION, TRAINING, AND UNIVERSITY LIAISON

A broad employee development program, implemented primarily through the NBS Graduate School and non-Government educational and training facilities, is available to all staff members. The program covers education through postdoctoral research and is offered at both the Boulder and Gaithersburg Laboratories. The primary objectives—to increase employee efficiency in assigned duties and to prepare systematically for increased responsibilities—are to an increasing extent encompassing the management and supervisory areas, as well as the traditional areas of science and technology.

The NBS Graduate School

The NBS Graduate School curriculum includes graduate and undergraduate courses in the physical sciences, mathematics and specialized branches of engineering. A series of scientific colloquia and seminars designed to update and continue the education of the postdoctoral scientist are led by research leaders from the Bureau and from other research centers and universities. In addition, general staff development courses, such as Scientific Russian, Reading Improvement, and special clerical and administrative conferences and workshops are offered. Two special programs, designed for technicians and subprofessional laboratory personnel offer courses both in-house and in cooperation with the Montgomery Junior College, leading to an NBS Technician Certificate, and/or the A.A. degree at the Montgomery Junior College. Surveys periodically redetermine course offerings and keep the program in step with the changes and variations in educational requirements.

An interesting variation of the basic theme finds the Graduate Program at Boulder associated with the University of Colorado in a Joint-Course program and Adjunct Professor Plan. Various graduate departments of the NBS Graduate School and the University offer courses which mutually benefit the Government and the University.

Since the establishment of the educational program in 1908, 44 universities have awarded 342 graduate degrees based partly on credits obtained for courses or thesis research carried on under the NBS Graduate School Program.

Non-Government Education

Non-government education falls into three categories—full-time (3 to 12 months) postdoctoral study and research assignments at universities and research centers; full-time (less than 3 months) attendance at institutes, seminars, short concentrated courses, and workshops; and part-time, job-rated academic courses at universities and in industry. In the last year 391 staff members at Washington and Boulder were trained through non-government facilities, and 7 career scientists were selected for full-time research assignments at universities and research centers. Participants in approved full-time training programs receive full salary and expenses, including tuition, fees, travel and per diem, as well as transportation of family and household effects. Three hundred and eighty-four employees, mostly from technical divisions, attend job-related courses on a semester basis, and shorter concentrated courses at universities and in industry.

PUBLICATIONS*

PUBLICATIONS IN THE BUREAU'S SERIES

During the year NBS publications totaled 902 published papers and documents.

Of the formal publications, 81 appeared in the Journal of Research, and 616 in the journals of professional and scientific societies. Also, 122 summary articles were presented in the Bureau's monthly Technical News Bulletin.

In the nonperiodical series, 83 documents were published: 9 in the Monograph series, 1 in the Handbook series, 18 in the Miscellaneous Publication series, 35 in the Technical Notes series, 8 Product Standards, 4 Commercial Standards, 4 National Standard Reference Data Series, 1 Building Science Series, and 1 Simplified Practice Recommendation.

Journal of Research. Contains full research papers, including laboratory data, experimental procedures, and theoretical and mathematical analyses. Advances in measurement standards and techniques . . . physical constants . . . properties of materials . . . instrumentation . . . radio propagation.

The Journal is published in three separate sections . . .

A. Physics and Chemistry, issued six times a year. Annual subscription: Domestic, $5; foreign, $6.00; single copy, $1.00.

B. Mathematics and Mathematical Physics, issued quarterly. Annual subscription: Domestic, $2.25; foreign, $2.75; single copy, 75 cents.

C. Engineering and Instrumentation, issued quarterly. Annual subscription: Domestic $2.75; foreign, $3.50; single copy, 75 cents.

Volume 70A (Phys. and Chem.), No. 4 (July–Aug. 1966)

Elastic constants of synthetic single crystal corundum. W. E. Tefft.

Phase equilibria as related to crystal structure in the system niobium pentoxide-tungsten trioxide. R. S. Roth, J. L. Waring.

Properties of aqueous mixtures of pure salts. Thermodynamics of the ternary system: water-calcium chloride-magnesium chloride at 25 °C. R. A. Robinson, V. E. Bower.

Properties of aqueous mixtures of pure salts. Thermodynamics of the ternary system: water-sodium chloride-calcium chloride at 25 °C. R. A. Robinson and V. E. Bower.

Use of the consistency check in the vector verification method. A. D. Mighell, R. A. Jacobson.

Self-reversal in the spectral lines of uranimum. D. D. Laun.

Oscillator strengths for ultraviolet lines of Fe I. C. H. Corliss, Brian Warner.

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*Publications for which a price is indicated are available by purchase from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (foreign postage, one-fourth additional). The NBS non-periodical series are also available from the clearinghouse for Federal Scientific and Technical Information, Springfield, Va. 22151. Reprints from outside journals and the NBS Journal of Research may often be obtained directly from the authors.

Volume 70A (Phys. and Chem.), No. 5 (Sept.–Oct. 1966)

Orientation of calcium molybdate ($CaMoO_4$) and other single crystals having the scheelite structure. E. N. Farabaugh, H. S. Peiser, J. B. Wachtman, Jr.

Crystal structure of $BaGe[Ge_3O_9]$ and its relation to benitoite. C. Robbins, A. Perloff, S. Block.

A rotating cylinder method for measuring normal spectral emittance of ceramic oxide specimens from 1200 to 1600 °K. H. E. Clark, D. G. Moore.

Electron absorption spectrum of cobalt (II)-doped trisphenanthroline-zinc nitrate dihydrate. C. W. Reimann.

Procedures for homogenous anionic polymerization. L. J. Fetters.

The configurations $4d^n+4d^{n-1}5s$ in doubly inoized palladium group. Y. Shadmi.

Volume 70A (Phys. and Chem.), No. 6 (Nov.–Dec. 1966)

Absolute isotopic abundance ratios and atomic weight of magnesium. Edward J. Catanzaro, T. J. Murphy, E. L. Garner, W. R. Shields.

Mass spectrometric study of photoionization V. Water and ammonia. V. H. Dibeler, J. A. Walker, H. M. Rosenstock.

Interpretation of the third spectrum of gold (Au III). L. Iglesias.

A formal solution for slit corrections in small-angle x-ray scattering. J. Mazur, A. M. Wims.

High-temperature reactions of hexafluorobenzene. J. M. Antonucci, L. A. Wall.

The melting temperatures of the *n*-paraffins and the convergence temperature for polyethylene. M. G. Broadhurst.

General treatment of the thermogravimetry of polymers. J. H. Flynn, L. A. Wall.

Viscoelastic behavior under large deformations. L. J. Zapas.

Statistical aspects of second and third law heats. W. S. Horton.

Density-temperature formulae for coexisting liquid and vapor and for freezing liquid parahydrogen. R. D. Goodwin.

Solubility of $CaHPO_4 \cdot 2H_2O$ and formation of ion pairs in the system $Ca(OH)_2$-H_3PO_4-H_2O at 37.5 °C. E. C. Moreno, T. M. Gregory, W. E. Brown.

Dissociation of some substituted phenols in 50-percent aqueous methanol as solvent. R. A. Robinson, R. G. Bates.

Volume 71A (Phys. and Chem.), No. 1 (Jan.–Feb. 1967)

Dedication of the new NBS laboratories.

Electric fields produced in cubic crystals by point defects. A. D. Franklin and D. J. Sparks.

Heat capacity and thermodynamic properties of beryllium 1:3-aluminate, $BeO \cdot 3Al_2O_3$, from 15 to 390 °K. G. T. Furukawa, W. G. Saba.

Dissociation constant of m-nitrophenol in 50 wt percent methanol-water solvent from 25 to 40 °C and related medium effects. B. J. Steel, R. A. Robinson, R. G. Bates.

On the calculation of moments of molecular weight distribution from sedimentation equilibrium data. I. H. Billick, M. Schulz, G. H. Weiss.

The far infrared spectrum of vulcanized natural rubber. J. E. Stewart, F. J. Linning.

Irradiation of dextran and its agueous solutions with cobalt-60 gamma rays. J. H. Flynn, L. A. Wall, W. L. Morrow.

Synthesis of poly-p-oxyperfluorobenzylene and related polymers. A novel synthesis of the monomer 2,3,5,6-tetrafluoro-4-trifluoromethylphenol J. M. Antonucci, L. A. Wall.

Preparation, purity, and homogeneity of NBS standard samples 705 and 706, polystyrene. D. McIntyre.

277-070 O—67——9

Large-scale, preparative paper chromatography. H. L. Frush.

Infrared absorption spectra of some aldofuranoid, aldopyranoid, and acyclic 1-acylamido derivatives of sugars. R. S. Tipson, A. S. Cerezo, V. Deulofeu, A. Cohen.

Volume 71A (Phys. and Chem.), No. 2 (Mar.–Apr. 1967)

Relative enthalpy of beryllium 1:1-aluminate, $BeO \cdot Al_2O_3$, from 273 to 1173 °K. Thermodynamic properties from 273 to 2150 °K. D. A. Ditmars, T. B. Douglas.

Relative enthalpy of beryllium 1:3-aluminate, $BeO \cdot 3Al_2O_3$, from 273 to 1173 °K. Thermodynamic properties from 273 to 2150 °K. D. A. Ditmars, T. B. Douglas.

The heats of combustion of polytetrafluoroethylene (Teflon) and graphite in elemental fluorine. E. S. Domalski, G. T. Armstrong.

Phase relations in the systems TiO_2-IrO_2 and SnO_2-IrO_2 in air. C. L. McDaniel, S. J. Schneider.

Sample purity and the N.Q.R. of Cl^{35} in $KClO_3$ at 0 °C. D. B. Utton.

Techniques for the growth of large single crystals of potassium of high purity. H. J. Foster, P. H. E. Meijer.

Synthesis of α-L-*fucose-l-*^{14}C (6-deoxy-L-galactose-*l-*^{14}C. H. S. Isbell, H. L. Frush, N. B. Holt.

Deuterium isotopes effects in α-β in the pyranose-furanose interconversions. H. S. Isbell, C. W. R. Wade.

Calculated transition strengths between the configurations $5d^8$ $6s$ and $5d^8$ $6p$ in Au III. H. Mendlowitz.

Hartree-Fock multiplet strengths for K I, Ca II, and Sc III. A. W. Weiss.

Oscillator strengths for the helium isoelectronic sequence. A. W. Weiss.

Solvent effects on the ultraviolet absorption of polystyrene. V. M. Story, D. McIntyre, J. H. O'Mara.

Volume 71A (Phys. and Chem.), No. 3 (May–June 1967)

Measured relative enthalpy of anhydrous crystalline aluminum trifluoride, AlF_3, from 273 to 1173 °K and derived thermodynamic properties from 273 to 1600 °K. T. B. Douglas, D. A. Ditmars.

The heat of formation of boron trifluoride by direct combination of the elements. E. S. Domalski, G. T. Armstrong.

An equation of state for fluid parahydrogen from the triple-point to 100 °K at pressures to 350 atmospheres. R. D. Goodwin.

The dissociation constants of some disubstituted anilines and phenols in aqueous solution at 25°C. R. A. Robinson.

Third virial coefficient for air-water vapor mixtures. R. W. Hyland, E. A. Mason.

Recrystallization and melting of partially melted stark rubber. D. E. Roberts.

Effects of a distribution of volume relaxation times in the annealing of BSC glass. P. B. Macedo, A. Napolitano.

Volume 70B (Math. and Math. Phys.), No. 3 (July–Sept. 1966)

Error bounds for asymptotic solutions of differential equations. I. The distinct eigenvalue case. F. Stenger.

Error bounds for asymptotic solutions of differential equations. II. The general case. F. Stenger.

On the approximation of functions of several variables. B. Mond, O. Shisha.

Finding a rank-maximizing matrix block. A. J. Goldman, M. Newman.

On certain discrete inequalities and their continuous analogs. A. M. Pfeffer.

Volume 70B (Math. and Math. Phys.), No. 4 (Oct.–Dec. 1966)

Dedication of the new NBS laboratories.
A random walk model of chain polymer adsorption at a surface. III. Mean square end-to-end distance. R. J. Rubin.
Abscissas and weights for Gaussian quadrature for N=2 to 100, and N=125, 150, 175, and 200. C. H. Love.
Transverse impact of a linear three-element spring and dashpot model filament: theory. J. C. Smith.
Functions for thermal stress calculation near a transient heat source on a flat surface. S. Jarvis, Jr., G. Hardy.

Volume 70B (Math. and Math. Phys.), No. 1 (Jan.–Mar. 1967)

Algorithms for frames and lineality spaces of cones. R. J.-B. Wets and C. Witzgall.
The coefficients of the powers of a polynomial. M. Newman.
Stable evaluation of polynomials. C. Mesztenyi, C. Witzgall.
On involutions. O. Shisha, C. B. Mehr.
Minimum number of subsets to distinguish individual elements. P. R. Meyers.
F-transforms. F. M. Ragab.
Three observations on nonnegative matrices. A. J. Hoffman.
Additional remarks on a theorem of M. Riesz. J. M. Smith.

Volume 70C (Engr. and Instr.), No. 3 (July–Sept. 1966)

Some harmonic properties of an oscillating Fabry-Perot interferometer. M. Gadsden, H. M. Williams.
Precise reflection coefficient measurements with an untuned reflectometer. W. E. Little, D. A. Ellerbruch.
A versatile ratio instrument for the high ratio comparison of voltage or resistance. A. E. Hess.
Console for the rapid and precise comparison of volt boxes. P. H. Lowrie, Jr.
Corrosion rates of binary alloys of nickel and iron measured by polarization methods. W. J. Schwerdtfeger.
The effect of cold-drawing on the creep behavior of a nickel–4.2 percent aluminum alloy. W. D. Jenkins, W. A. Willard.
Magnetic transformation and the influence of plastic strain on the shear modulus of Fe-Cr-Ni alloys. R. P. Mikesell, R. P. Reed.

Volume 70C (Engr. and Instr.), No. 4 Oct.–Dec. 1966)

Some techniques for measuring small mutual inductances. D. N. Homan.
Deflection of centrally loaded thin circular elastic plates on equally spaced point supports. A. F. Kirstein, W. H. Pell, R. M. Woolley, L. J. Davis.
Reproducibility of germanium resistance thermometers at 4.2 °K. M. H. Edlow, H. H. Plumb.
Calibration of vibrating-sample magnetometers. W. E. Case, R. D. Harrington.
Notes on the use of propagation of error formulas. H. H. Ku.
The apparent thermal radiation properties of an isothermal V-groove with specularly reflecting walls. R. B. Zipin.

Volume 71C (Engr. and Instr.), No. 1 (Jan.–Mar. 1967)

Dedication of the new NBS laboratories.

Symmetrical bending of thin circular elastic plates on equally spaced point supports. A. F. Kirstein, R. M. Woolley.

Ultrasonic measurement of cylinder expansion at pressures to 40 kilobars. P. L. M. Heydemann, J. C. Houck.

A comparison of absorbed dose determinations in graphite by cavity ionization measurements and by calorimetry. B. Petree, P. Lamperti.

Germanium resistance thermometry in the range 2.1 to 5.0 °K. M. H. Edlow, H. H. Plumb.

Least squares technique for the analysis of periodic temperatures of the earth's surface region. T. Kusuda.

A new near-zone electric-field strength meter. F. M. Greene.

Inductance and characteristic impedance of a strip-transmission line. R. L. Brooke, C. A. Hoer, C. H. Love.

Tensor permeability measurements at L-band frequencies using a degenerate mode cavity. L. B. Schmidt, R. D. Harrington, W. E. Case.

Volume 71C (Engr. and Instr.), No. 2 (Apr.–June 1967)

An apparatus for measuring thermal expansion at elevated temperatures. B. D. Rothrock, R. K. Kirby.

Determination and smoothing of Fourier coefficients representing piecewise continuous functions. B. A. Peavy.

A 2:1 ratio inductive voltage divider with less than 0.1 ppm error to 1 MHz. C. A. Hoer, W. L. Smith.

A dual-load flow calorimeter for rf power measurement to 4 GHz. M. L. Crawford, P. A. Hudson.

Polymeric materials for dielectric reference specimens. A. H. Scott, J. R. Kinard, Jr.

The sensitivity of the Dicke radiometer. D. F. Wait.

Sensitivity of a correlation radiometer. J. J. Faris.

Technical News Bulletin. This monthly publication summarizes the current research, development, and test activities of the Bureau. The articles are brief, with emphasis on the results of research and their significance, chosen for their importance to other scientists, engineers, and to industry. Résumés of longer research reports, important national and international conferences on fundamental science in which the Bureau has represented the Nation, and bibliography of all publications by members of the staff as published are included. The Bulletin is designed to give a succinct account of the current work of the Bureau. (Annual subscription: domestic, $1.50; foreign, $2.25.)

Monographs. These are usually contributions to the technical literature which are too lengthy for publication in the Journal of Research. They often provide extensive compilations of information on subjects related to the Bureau's technical program. Until July 1959 most of this type of material was published in the Circular series.

27. Supplement 2. Bibliography of temperature measurement, July 1960 to December 1965, L. O. Olsen and C. Halpern. April 28, 1967. (Supersedes Suppl. 1 to Monograph 27) 35 cents.

61. The solar spectrum 2935Å to 8770Å. Second revision of Rowland's preliminary table of solar spectrum wavelengths, C. E. Moore, M. G. J. Minnaert, and J. Houtgast. December 1966. $4.00.

75. Colors of signal lights. Their selection, definition, measurement, production, and use, F. C. Breckenridge. April 3, 1967. 40 cents.
88. Heat treatment and properties of iron and steel, T. G. Digges, S. J. Rosenberg, and G. W. Geil. November 1, 1966. (Supersedes Circular 495 and Monograph 18) 35 cents.
96. Electrical parameters of precision, coaxial, air-dielectric transmission lines, R. E. Nelson and M. R. Coryell. June 30, 1966. $1.25.
97. Microwave attenuation measurements and standards, R. W. Beatty. April 3, 1967. 25 cents.
98. Abscissas and weights for Gaussian Quadrature for N=2 to 100, and N=125, 150, 175, and 200, C. H. Love. December 28, 1966. 55 cents.
99. Automatic typographic-quality typesetting techniques: A state-of-the-art review, M. E. Stevens and J. L. Little. April 7, 1967. 70 cents.
100. Trace characterization, chemical and physics, Editors, W. W. Meinke and B. F. Scribner. April 28, 1967. $4.50.

Handbooks. These are recommended codes of engineering and industrial practices, including safety codes, developed in cooperation with the national organizations and others concerned. In many cases the recommended requirements are given official status through their incorporation in local ordinances by State and municipal regulatory bodies.

102. ASTM metric practice guide. March 10, 1967. 40 cents.

Miscellaneous Publications. As the name implies, this series includes material which, because of its character or because of its size, does not fit into any of the other regular publication series. Some of these are charts, administrative pamphlets, Annual Reports, Weights and Measures Conference Reports, and other subjects appropriate to the Miscellaneous series.

236. 1967 edition. NBS Standard frequency and time services Radio stations WWV, WWVH, WWVB, WWVL, 1967. 15 cents.
240 Suppl. Publications of the National Bureau of Standards, July 1960 through June 1966 (includes papers published by others 1960 through 1965). Together with subject and authors indexes, B. L. Oberholtzer. April 3, 1967. $4.00.
260–11. Standard Reference Materials: Viscosity of a standard lead-silica glass, A. Napolitano and E. G. Hawkins. November 7, 1966. 25 cents.
260-12. Standard Reference Materials: Homogeneity characterization of NBS spectrometric standards III: White cast iron and stainless steel powder compact, H. Yakowitz, D. L. Vieth, and R. E. Michaelis. September 19, 1966. 20 cents.
260–14. Standard Reference Materials: Determinaiton of oxygen in ferrous materials SRM 1090, 1091, and 1092, O. Menis and J. T. Sterling. September 23, 1966. 30 cents.
262–2. Legibility of alphanumeric characters and other symbols. II. A reference handbook, D. Y. Cornog and F. C. Rose, February 10, 1967. $4.25.
265. Dimensional metrology. Subject-classificed with abstracts, I. H. Fullmer. August 1, 1966. $3.00.
273. Critical phenomena. Proceedings of a conference, Washington, D.C., 1965, Edited by M. S. Green and J. V. Sengers. December 1, 1966. $2.50
274. Periodicals and serials received in the Library of the National Bureau of Standards as of October 1965, N. J. Hopper. July 1, 1966. (Supersedes Monograph 57) 50 cents.
280. Hydraulic research in the United States 1966, Edited by H. K. Middleton and G. Kulin. September 8, 1966. $1.50.

281. Bibliography on flame spectroscopy analytical applications 1800–1966, R. Mavrodineanu. February 23, 1967. $2.00.
282. The National Bureau of Standards 1966. November 1966. 35 cents.
283. Technical highlights of the National Bureau of Standards, Annual Report 1966. April 1967. 60 cents.
284. Technology and world trade, proceedings of a symposium, Edited by R. L. Stern. 1967. $1.25.
285. Nuclear science and technology for ceramists. Proceedings of the American Ceramic Society Symposium, Washington, D.C., April 7–12, 1966. May 26, 1967. $1.75.
286. Units of weight and measure. International (metric) and U.S. Customary, L. J. Chisholm. May 1967. (Supersedes Miscellaneous Publ. 233) $1.50.
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PATENTS

The following U.S. Patents have been granted to Commerce inventors; assigned to the United States of America, as represented by the Secretary of the department noted in parentheses:

Berlinsky, Anthony A.; Fay, William T.; and Brennan, Martin J. No. 3,264,739, August 9, 1966. Apparatus for Measuring Area (Commerce).
Wall, Leo A., and Antonucci, Joseph M. No. 3,265,746, August 9, 1966. Method of Making Perfluorostyrene (Navy).
Cook, Herbert D. No. 3,270,189, August 30, 1966. Device for Determining an Angle from a Set of Orthogonal Components (Commerce).
Shapiro, Gustave, and Stone, Robert O. No. 3,273,160, September 13, 1966. Indenting Recorder with Illumination Means (Commerce).
Palumbo, Francis J. No. 3,276,062, October 4, 1966, Mercury-Adsorbent Retrieving Devices (Commerce).
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Cassidy, Esther C., and Tsai, Donald H. No. 3,282,187, November 1, 1966. Fast-Operating, Large-Aperture Shutter (Commerce).
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Miller, Charles E., and Jacobs, Robert B. No. 3,298,221, January 17, 1967. Densitometer (NASA).
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Henig, Seymour, and Palasky, Ervin C. No. 3,300,066, January 24, 1967. Sorting Machine Providing Self-Optimizing Inventory Reduction (Commerce).
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